Chiropractic Physiology

VEDDER

A TEXT BOOK

ON

CHIROPRACTIC PHYSIOLOGY

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DEDICATION

Few subjects in the study of Chiropractic offer such a wealth of material which an author is able to mold as does the subject of Physiology. It is not confined to the study of the concrete alone, but to the activity which occurs in that concrete, dependent upon the expression of the immaterial thru it. The author has been very materially aided in the compilation of this volume by the assistance which has been so kindly extended to him by Dr. B. J. Palmer.

Because of the deep insight of this man, and because he has made hours of sacrifice in discussing its principle and assisting in its production, this book is respectfully dedicated to B. J. Palmer, D. C., Ph. C.

HARRY E. VEDDER, D. C., Ph. C.

PREFACE

Having occupied the chair of Physiology in the Palmer School of Chiropractic for the past five years, I have become aware of a greater and more insistent demand for a text book which should base its reasoning upon the Chiropractic Philosophy. Students and sincere investigators who had studied the standard authorities on Physiology discover that these books base the functions of the body upon the application of chemical and physical laws, but carry their reasoning no further.

Chiropractic philosophy delves into the study of the abstract to the very source of life, and in the following pages it is the endeavor of the author to scientifically explain the functions of the body, by the application of the principles of the abstract. Chiropractic Physiology is the connecting link which explains the application of the immaterial upon the material.

Several years have been spent in gathering the material for this volume, and hours of study and research work have been devoted that it might in the clearest and most concise manner reveal to the profession at large and the student in particular the basic principles upon which the function of the body is dependent.

It is the sincere hope that its purpose has been accomplished and that it will supply a long felt need in the Chiropractic world.

HARRY E. VEDDER, D. C., Ph. C.

CONTENTS

SECTION 1.

Introduction.

SECTION 2.

SECTION 3.

SECTION 4.

SECTION 5.

SECTION 6.

SECTION 7.

SECTION 8.

SECTION 9.

SECTION 10.

SECTION 11.

SECTION 12.

SECTION I

INTRODUCTION

In considering Physiology from a Chiropractic standpoint, there is much that may be said more than is given in any other text book on Physiology. This, because Chiropractic deals with "life" that has not been dealt with by scientists of the past or any other scientific teaching of the present.

Physiology treats of the functions of the body; that is, it deals with the problems of their work and the proposition of its execution. This, however, is said to be dependent upon two principles namely, the laws of Chemistry and the laws of Physics. In other words, the same laws that govern the action of inanimate bodies (and these are only the laws of Chemistry and Physics) govern the living organism.

The Chiropractor assumes an entirely broader viewpoint. There is no question but that the laws of Chemistry and Physics are involved in the functioning of the human body. But, these laws of Chemistry and Physics are in turn governed and controlled by a higher power, an immaterial force which we have called Innate (inborn) Intelligence.

As we, in our study of all phases of science, allow our imaginations to wander, we think of the planets of the universe, which we can recall, that are of the greatest distance imaginable from the earth and then we attempt to assume a viewpoint which will give us something tangible and definite.

We try to imagine a place where space stops and we are unable to conceive of such a possibility and still we are unable to conceive of an unending space; of an unending distance. Further,

we try to imagine a condition wherein there is no longer time and we fail utterly. Thus we realize the incompetence of the human mind in grasping the simple details of life. We in ourselves are very delicately constructed pieces of machinery, but we are more than this; we are not automatons, but rather bodies which are absolutely under the control of a mind. This mind is intellectual and is only a segment or part of that great aggregation of power which we are pleased to name Universal Intelligence. It is called by different names; by some, nature, by others vitality, but in reality it is merely the expression of a power which governs and controls the universe. Therefore, to the best of our ability, we will attempt in the following pages to show how this Innate Intelligence governs the chemical and physical action in the body and what these actions are. We will not attempt to say what the force or power is that is working through the nervous system of the human body and causing it to be a living, thinking, reasoning mass of protoplasm.

Biology is the science that deals with life and is divided into Physiology and Anatomy. Anatomy deals with the structure of a part and must be, to a greater or less degree, studied in connection with Physiology, because the function cannot be ascertained unless we are aware of the structure. Not only is the structure of the body important in the study of physiology, but there enters into our constructive process a second element upon which physiology depends. Philosophy is the purely mental process of collecting the various laws and principles which govern any branch of study. The philosophy then of Chiropractic embraces the controlling principles of the human body. Physiology then being the term applied to the manner in which the various organs function must be the application of the philosophy of Chiropractic to the purely material structure, which is revealed by the study of anatomy. Anatomy is absolutely physical and of itself reveals nothing more than matter. Philosophy is absolutely immaterial and its study alone is of no practical value. Physiology is the ultimate blending of the two, explaining the application of the

one with the other, and if studied in an intelligent manner serves to bind them both into one common unit, which we are pleased to call life. Physiology may be further divided, depending upon whether it treats of the animal or vegetable organisms. Animal Physiology is further specialized upon in the human body and this branch is called Human Physiology. It is to this great field of study that we will turn our attention in future pages.

We may say that the entire human body is a unit which consists of a definite number of systems and in the normal individual these systems work at all times in harmony with one another. On the other hand each of these individual systems may be subdivided into organs. The organs are still further subdivided into various kinds of tissues distinguished because of difference in histological structure; that is, the organ is composed of many types of tissue. The tissues may be further subdivided into fibers and the fibers may be still further subdivided into cells. When we have approached this degree of division we must stop, because the cell is the smallest unit of structure which is found in man.

The cell is made up of various chemical elements, and of course, these chemical elements may be dissociated one from the other, but the cell is the smallest anatomical structure that is found as a unit in the human body.

It may be that in future years as the microscopic field becomes more and more proficient, that we will be able to find still further subdivisions other than those which have been discovered during the past.

As examples of the various systems of the body we may mention the respiratory system, which has to do with the passage of air into the lungs and the interchanging of parts of this air into the blood, which is contained in the capillary system of the pulmonary circulation. We may consider as one of the systems, the alimentary canal and accessory structures, which include many different organs, such as the liver, the pancreas, the salivary glands, etc., comprising in all the digestive system. The circulatory system consists of the heart, the arteries, arterioles, capil-

laries, venules and veins, together with the blood which circulates in these vessels. The skeletal system consists of all the bones of the body whose function it is to offer a support and a protection to the softer parts. The muscular system is, as the name implies, composed of the muscles of the body and it is their function, by their origin and attachment and because of their peculiar ability to contract, to produce movements throughout the entire human structure. The serous system is a complicated network of vessels and channels extending to every part of the body, supplying it with nutrition and conveying from it those materials which are no longer necessary. The excretory system consists of every organ, such as the kidneys or the skin, which in any way eliminates a waste from the body. The nervous tissue comprises that system in which we, as Chiropractors, are essentially interested. It is the system which has its center in the cranial cavity, extending from there through the spinal column and emanating from here to all the other systems of the body. It is that system which is a medium through which Innate Intelligence controls all the other systems of the body. Therefore, if any other part of the body becomes abnormal, pathological, it is because of the fact that it is not being controlled properly, and we must look for the cause of this abnormality at some point in the nervous system.

In the consideration of the tissues of the body we find that there are four elemental structures, each one of which has a peculiarity. Thus, as a house is composed of wood, of metal, of paper, etc., the body is composed of various kinds of structures. These elementary tissues are called:

Epithelial tissue.
Connective tissue.
Muscular tissue.
Nervous tissue.

We may further subdivide each of these four elementary tissues.

With regard to the fibers, we may say that they vary somewhat in their qualities. Some fibers are strong, tough and hard;

other fibers may be soft, easily lacerated and possibly of a different color, size, etc. These differences may be accounted for by the difference in the unit cells and the manner in which they are joined together.

We have said that each fiber is formed by a combination of unit cells; then the fibers differ because of the difference in the structures forming them. This being true, the cells must differ materially in their structure. They do differ somewhat, but the difference is accounted for largely by the difference in the amount of cementing material which is found holding the cells together. Thus in some parts of the body we have a great number of cellular structures with a small quantity of cementing material holding the cells together, and this is illustrated in epithelium. Further we have what is known as connective tissue, so named because of the large amount of cementing material between the cells, which easily connects, joins and supports the various surrounding parts.

The term cell was originated first in the study of the plants. A space surrounded by a wall, was called by botanists a cell. In plant life structure is not so compact as in the majority of animal tissues. Then, too, in the plant life there is always a surrounding wall, while this is not true in the animal kingdom. The little vacuoles filled with a watery fluid, which are found in the vegetable world within the cell, are not found to the same degree in animal life. The animal cell very often is devoid of a cell wall or a surrounding membrane. It is merely a small mass of living matter having certain peculiar qualities, and is called protoplasm.

The very simplest animals and plants consist of merely one cell and these living units are called unicellular because of this fact. Every plant and every animal of the higher type is claimed by most authorities to have had its beginning in a single cell, and this cell expands and grows until finally the adult developed unit of life is produced.

There are five qualities which are present in living organisms that are said to be characteristic of life. The most important of

these are the first two: the power of assimilation and the power of excretion.

Assimilation is the ability of the organism to take into its body food materials from the external, digesting them and making them a part of itself. In other words, converting this food into such a form that it becomes a part of the body.

The power of excretion is the ability of the organism to give off waste matters, which not only are no longer of use in the body, but which may be detrimental to the organism if retained.

The student should learn to distinguish between excretion and secretion. Secretion is something formed by the body to be used in the body and has a definite function.

Adaptability is the third principal sign of life and is the intellectual ability that the organism possesses of responding to some vibration. This response may be in the form of motion, in the form of reasoning, or in various other ways.

The fourth sign of life is the power of growth which is just as the name implies, the power to expand, and is dependent upon the power of assimilation.

The fifth is the power of reproduction; the ability of the unit to produce something of like kind. It is really dependent upon the power of growth and the power of assimilation.

We do not mean to say that all of these five principal signs must be present to prove the object living, because in some living units there may be one or two present and these may be latent to such a degree that we are unable to determine accurately as to whether life exists or not.

We may say at the conclusion of this chapter that all living organisms are in a continual state of change. The chemical composition of the cell is being broken down and built up at all times. The different degrees of combination are constantly changing. This tearing down process which is going on in living organisms at all times, is known as the process of katabolism. At the same time there is continually progressing a building up process and this is known as the process of anabolism. The combination of these two is known as metabolism.

SECTION II

ELEMENTARY TISSUES

CHAPTER I

THE CELL

Cells of the human body are microscopic in size, usually varying from 1/300 to 1/3000 of an inch in diameter.

We may say that there are three distinct parts of the cell, and they are—

First—The protoplasm.
Second—The nucleus.
Third—The centrosome and centrosphere.

PROTOPLASM

The protoplasm makes up the great bulk and substance of the cell body and, until the higher development of the microscope, it was thought to be merely a structureless mass with a few vacuoles or spaces containing fluid and a few particles of solid granular structure. It has, however, been discovered that the protoplasm is formed of two specific and distinct structures. First: There is a network of fibrillæ, which is of a more solid consistency than is the other part, while the softer structure seems to be more of a watery, slimy consistency. This network or supporting structure is known as the spongioplasm or reticulum, and the softer fluid element is known as hyaloplasm or enchylema. In this hyaloplasm we have little loose solid particles, which are formed of pigment and fat, and these are known as the cell contents; sometimes known as paraplasm.

NUCLEUS

With regard to the nucleus of the cell, we may say that it is generally spherical or elliptical, but it may have any irregular shape. Sometimes there is one and sometimes there are more than one. The nucleus is located usually in the centre of the cell, but it may be found in any portion thereof. The nucleus has some controlling influence over the vitality of the cell, because if any portion of the protoplasm is cut off from its communication with the nucleus, it immediately undergoes degenerative changes.

The nucleus is subdivided into four specific and distinct structures.

First: We have the nuclear membrane, which is merely a surrounding structure separating the body of the nucleus from the protoplasm of the cell.

Second: The chromoplasm, which is the same to the nucleus as the spongioplasm is to the protoplasm. However, the chromoplasmic fibers are much coarser here and much more easily seen than the spongioplasm fibers of the cell. They may be divided into two kinds. The heavy fibers are known as the primary chromoplasmic fibers, while the fine thin ones are known as the secondary.

The third structure which we find in the nucleus is the nuclear sap or the matrix. It is to the nucleus exactly as the hyaloplasm is to the protoplasm, namely, the fluid substance which is found in the interspaces of the chromoplasm.

The fourth structure found in the nucleus is the nucleolus. There are usually a number of these nucleoli. They are small masses of granular matter floating in the substance of the nuclear sap. We have thickened portions of the chromoplasm which are apparently granular bodies. They, however, are called pseudonucleoli because they are not floating loosely in the matrix.

CENTROSOME AND ATTRACTION SPHERE

The attraction sphere or the centrosphere is merely that part of the protoplasm over which the centrosome has an attract-

ive influence. The centrosome is a small granular body located as a loose floating particle in the protoplasm and this small body has a magnetic influence upon the cell contents or the loose floating particles of the protoplasm known as paraplasm; because of this fact it is known as the centrosome. These particles under the influence of this force arrange themselves in definite lines. As the rays of light radiate from the sun, so these granules of paraplasm radiate in all directions from the centrosome. The range over which this centrosome has an attractive influence is known as the centrosphere or the attraction sphere. It merely designates that area in which the influence of the centrosome is felt. As a rule there is just one controsome in each cell, but some cells contain more than one.

CELL EXPANSION

We now approach the important subject of the growth of the body and the means whereby this is accomplished. Formerly it was the contention that cells divided and redivided as new cells were needed in the development of the body, and in maintaining its structure even after the maximum size was reached.

Chiropractic has, however, advanced the idea that at the time of impregnation of the ovum all the cells of the body which are to be used in the development and in the maintaining of its structure are contained in this small mass. The cells, however, at this time are not in the expanded state, nor do they expand until the impulses of expansion are sent to them by Innate Intelligence, whereby they are enabled to attain such size as shall be of benefit in the general process of growth.

There are many features which uphold this explanation of the bodily development. In the first place if the theory of cell division were accepted to explain growth and the replacing of worn out tissues, the individual would live indefinitely so long as the path from Innate to tissue cell were not interrupted. This we know is not the case. After a certain number of years the body, because its cells have all been used, is not a fit habitation for Innate and the natural consequence is death.

Then, too, we know that in the periosteum of the bone are minute areas which are known as centers of ossification, and it is from these areas that cells and fibrils are sent into the substance of bone to produce its growth and enlargement. This fact is equally true in other kinds of tissue. We know that if certain parts of the connective tissues are removed, the wound heals and after a time there is no evidence of the part having been excised. On the other hand there are certain areas which, if removed, leave a deep cicatrix and the tissue which is absent is never replaced.

All this leads us to the conclusion that these developmental centers in the soft tissues are placed very closely together and are concerned in sending out unexpanded cells, which upon reaching the location where they will be of use are expanded and utilized until they are no longer able to perform their function. They are then disintegrated by Innate Intelligence and carried away by the serous circulation to organs which eliminate them from the body, and their places are taken by new cells expanded from the centers of development.

The contention might arise that this explanation would lead back through generation after generation until we would have to assume that the cells in the human race were all primarily in the bodies of the first of our forefathers. This, however, is not true, because the ovum and the spermatazoon are secretions formed by glandular organs just as bile is formed by the liver. These secretions are the result of the functional activity of the glandular cells, but take nothing from these cells. Rather they are manufactured by the secreting cells from the nutritive substances conveyed to them by the serous circulation.

Bearing this viewpoint in mind we can readily see how the original cellular elements of the foetus are the result, not of the depletion of the bodies of our forefathers, but rather to the activity of the cells of these former bodies carried on as the direct result of reproductive impulses sent to the organs of reproduction by the Innate Intelligence.

CHAPTER II

EPITHELIAL TISSUE

In our study of previous chapters we have determined that the tissues whish go to make up the organs of the body are divided into four sets. These are known as epithelial, connective, muscular and nervous.

The epithelial tissues we will study first because of the fact that they are composed of a maximum amount of cellular material and a minimum amount of cementing substance. We may say that generally epithelial tissue is found lining a cavity or covering the surface of an organ.

The two main subdivisions of epithelium are called the simple and compound. Simple epithelium is just as the name implies, an epithelial tissue which is composed of just one layer of cells, and it, in turn, may be subdivided into several minor groups. They are, the pavement, cubical, columnar, spherical and ciliated.

PAVEMENT EPITHELIUM

Pavement epithelium is so named because it resembles the arrangement of a mosiac pavement wherein the blocks are very thin and flat, polyhedral in shape, and held together by an extremely small amount of cementing material. It is found especially in the air sacs of the lungs; forming the lining of blood vessels and lymphatic vessels; also forming the lining of serous sacs. In all of these places except in the air sacs of the lungs it is considered as endothelium rather than epithelium, in that it is of mesoblastic origin rather than of epiblastic origin, as are all the other epithelia. The structures, however, are identical one with the other.

CUBICAL EPITHELIUM

The second division is known as simple cubical epithelium, and here, as the name implies, the cells are of a cubical shape and, being a simple epithelium, form a single layer. This form of epithelium is found in the ducts of the testes, in the alveoli of the thyroid gland, and in many other glandular structures throughout the body.

COLUMNAR EPITHELIUM

Columnar epithelium is also named from the shape of its cells. Especially do we find this type of simple epithelium in the alimentary canal throughout the small and large intestines. There is a peculiarity in the columnar and in the cubical cells which we should at this time note. It is found upon examining a transverse section of columnar and cubical epithelium that there are small spaces or openings found at the free extremities of some of the cells, but upon further examination we learn that this effect is brought about by the presence of what are known as goblet cells. These goblet cells are cellular masses of protoplasm found between the true columnar cells. At their free end they fill with a substance known as mucin, which, after it gathers in sufficient quantities is discharged, and forms the principal part of the mucus in every mucous membrane.

SPHERICAL EPITHELIUM

Now we approach the fourth variety, which is the spherical form. These small spherical cells are found in some of the glands of the body and are, as the name implies, spheroidal in shape and have in reality practically the same function as do the other types of simple epithelium.

CILIATED EPITHELIUM

Ciliated epithelium is the name applied to that form of columnar epithelium which contains cells surmounted by small

projections of protoplasm. These are usually from eight to twenty in number projecting from the free end of the columnar cell in the form of cilia or hairs, hence the application of the term.

It is not always true that the columnar cells are surmounted by these cilia, nor can we say that the cilia when present are always mounted upon columnar cells. They may be found upon cubical or spheroidal cells as well. The student should not conceive the idea that because these projections are hair-like in shape, that they are hair-like in structure. They are not composed of the same kind of material as are the hairs of the body but are merely projections in a peculiar shape of the protoplasm of the cell.

Naturally the question arises as to the function of this peculiar type of epithelial tissue. It has the function of producing a wave-like motion in one direction. This is always toward the external, and by means of it the cilia propel toward the external any foreign material which may be found on the surface of the membrance.

Each individual cilia relaxes and then straightens up again, and this same movement is repeated time after time, and in observation of a mass of these cilia, one may see that it resembles in appearance that of a field of grain with the wind blowing over it or of a large body of water with the swells moving always in one direction.

Ciliated epithelium is located in the lining of the air passages where it works continuously toward the external, thus propelling any dust particles or foreign matters in the same direction. It also propels the mucus which is formed by the goblet cells toward the external, and thus we have at all times the expulsion from the throat of a certain amount of mucus. This type is also found to be present in the Fallopian tubes and in the uterus, in the ducts of the testes, in the ventricles of the brain, in the central canal of the spinal cord, and many observers

maintain that the tail of the spermatozoon is merely an elongated cilium.

In some animals the cilia are found in other places, and especially do we find them in the gullet of frogs, placed here toward the stomach, so as to aid in the deglutition of foods. We may say in conclusion that the cilia move under the control of Innate Intelligence, although some investigators maintain that this movement is independent of the nervous system; it may be that it is not directly dependent upon it, but directly or indirectly every tissue of the body is dependent upon the nervous system, because it is the great transmitter for the mental impulses emanating from the brain.

In considering that it is dependent upon a chemical or a physical action which in reality may be true, still we must remember that in the human body this chemical or physical action is in turn dependent upon the Innate control through the nervous system. The straightening up and bending over process which each individual cilium goes through during a definite period of time is the result of an increased pressure progressing rythmically in each one of the cilia. This increase is due to the flowing in of the protoplasm from the main body of the cell and following this, the flowing out of the protoplasm, thus first increasing and then decreasing the pressure and tending to tense and then relax each one of the cilia.

We will now consider the second great division of the epithelial tissue, which is known as the compound epithelium. This type is just as the name implies, wherein the cells, rather than being arranged in a single layer, are arranged in several layers, and the type may be divided into two main kinds, the first of which is known as transitional epithelium; the second as stratified epithelium.

TRANSITIONAL EPITHELIUM

The transitional form is found in the lower part of the uterus and lining the urinary bladder, and is spoken of as

transitional because it seems to be in a transitory stage between a simple and a true compound epithelium. It is not simple because there is more than one layer of cells, but it is not a true compound because the cells which are present are not arranged in regular layers. While it is three or four cells deep, each cell seems to be independent in itself, rather than in direct alignment with any other cell or group of cells.

STRATIFIED EPITHELIUM

Stratified epithelium is a direct compound epithelial tissue, found especially forming the epidermis or the false skin of the body and lining the various orifices. It is also found extending from the mouth through the alimentary canal to the cardiac valve of the stomach. It is formed of a number of layers of cells one above the other. Usually the deep layers are columnar, those next in order are cubical and the surface cells themselves are of the pavement type, being merely flattened scales and are elements of what were once the deep columnar cells.

The cellular origin is a peculiar one in that the new cells are continually supplied from below. These cells push upward and as the outer scale-like cells are worn off they are replaced by the lower cubical cells. Their place is in turn filled by the columnar cells. Thus we have a continual movement from beneath toward the surface.

The cells of the epidermis especially contain large quantities of keratin, which is a hard horny material. Epithelial tissue in some regions does not contain blood vessels and the question naturally arises as to how its nourishment is supplied. This difficulty is overcome by the fact that there are small serous channels between the cells and the lymph oozes out through the walls of the small capillaries, thus finding its way into the epithelial tissue by means of these small channels and supplying the cells in this manner with nutritive material.

The function of epithelial tissue varies in different parts

of the body, but the cells which are found comprising it are usually of the secreting variety. The secreting cells of every gland in the body are of the epithelial variety, which under the control of Innate Intelligence, have the power of taking from the blood, lymph and serum those materials which are needed in the formation of their peculiar secretion, altering these materials within their bodies and passing them out as a secretion. This is true of the cells of the pancreas, the liver, the small glands of the alimentary canal, and all other glands. Some authorities hold that this selective influence of the cells is an inherent quality of the cell itself and is due to the chemical affinity which the cell holds toward certain chemical elements. This explanation, however, is hardly satisfactory, and we must revert again to the basis of Chiropractic, which holds that while the laws of chemistry and physics do exist in the living body, that there must be something else which is vital in controlling the activity of each and every cell. This is proven by the fact that certain epithelial glandular cells have an active function only at certain times, as, for instance, the cells of the pancreas. Here we have the cells emptying themselves into the channels which lead directly to the alimentary canal only at those times when there is food in the canal to be acted on by this fluid. The only possible explanation of this fact is that of the nervous system. The Innate Intelligence upon interpretation of the afferent impressions becomes aware that certain kinds of food are in the alimentary canal and should be acted upon by the pancreatic juices. Efferent impulses are therefore sent down to the cells of the pancreas and their secretion is unloaded, and passes to the canal. We must ultimately rely on the presence of Innate to explain every functioning process in the body. If this were not true death could not occur, because the material is always present and the laws of chemistry and physics always remain the same. Death is merely the absence of Innate, and thus the absence of a controlling factor in the material.

CHAPTER III

CONNECTIVE TISSUE

In the consideration of the subject of connective tissue, we may say that there are nine principle divisions. The first of these is the areolar tissue, so named because of its many interspaces. The second is known as fibrous tissue, and is so named because of the great number of white fibers therein contained. The third is called the elastic tissue and is, as the name implies, composed largely of elastic fibers. Adipose tissue is the next division and is a term applied to connective tissue wherein fatty oils predominate. The fifth division consists of retiform and lymphoid tissues. The first so named because of its interspaces, the second because of the great quantities of lymphocytes in its meshes. The sixth is the jelly-like connective tissue, and is so named because of its very soft consistency. Cartilage is the seventh and is a hard gristly substance found in many parts of the body. Bone and dentine come under the eighth division and their distribution is also very wide. The last division of the connective tissue is blood, so soft that it is continually changing shape and yet in reality a true connective tissue.

It is often the case that the student, in studying the connective tissues for the first time, believes that there is nothing in common between the different forms of them, and cannot comprehend why they should be classed under one heading. They may be so classed for several reasons.

In the first place they are all derived from the middle layer of the embryo, therefore, have the same origin. They resemble each other so far as structure is concerned, because each con-

nective tissue, whether bone or blood, contains a maximum quantity of intercellular material and a minimum quantity of cellular elements. Further than this, they resemble each other so far as their function is concerned, because they bind together the softer tissues of the body and act as a support in holding the other tissues in their respective positions.

It seems especially hard for the student to conceive of how blood and bone may be considered under one head. This is because blood seems to us to be a fluid, and we are in the habit of thinking of tissues as solid material. However, there is only a step between blood and muscular tissue in the comparative fluid elements that are contained in them.

Muscle, for example, is composed of at least three-fourths water, while blood is only slightly more liquid than this. Blood, on the other hand, while considered as a fluid, in reality is a tissue containing definite kinds and numbers of cells. These cells are connected by intercellular material which we speak of as blood plasma. The blood also has its derivation from the mesoblast, and so it can be readily seen that in reality it is a true connective tissue.

AREOLAR TISSUE

Areolar tissue is one of the most common of the connective tissues distributed throughout the entire body and is found below all serous and mucous tissues and below the surface of the skin. It also forms coverings for muscles, glands, blood vessels and many other of the softer structures, binding them into a common mass and penetrating their structure, giving to the substance of the individual organ a framework which the softer parts may be supported by.

There are in reality four structures to be remembered in the description of areolar tissue. They are: Cellular elements, ground substance, white fibers and yellow fibers. The cells or corpuscles may be of several kinds. We may have what are

known as the wander cells, which are minute white blood corpuscles, having found their way through the pseudo-stomata of the capillary system and thus come into direct contact with the surrounding tissue. Pigment cells are found giving color to the tissue here as in many other parts of the body. We also have what are known as flattened cells, some of which are branched and some unbranched. These branched cells send out their projections in various directions and join with other cells of various types while the unbranched cells fit in their borders very similar to the arrangement of the pavement cells of the simple pavement epithelium. We have the plasma cells of Waldeyer, which are irregular in form and size, and whose chief characteristic is the fact that they contain great numbers of vacuoles. Granular cells are practically the same in size and shape as the cells of Waldeyer and differ in that, instead of containing the large number of vacuoles, they contain small albuminous granules.

The ground substance or matrix is found forming a large bulk of the areolar tissue, and is the softest part of the entire structure, binding together not only the cells which we have described but also joining these cells with the two kinds of fibers which are abundantly distributed throughout the tissue. This ground substance contains within itself small tubules which connect the cells one with the other, and their function is to convey serum and lymph to the more solid structures of the tissue, and thus supply them with nutriment. This lymph and serum is derived from the small capillaries where they come in contact with the areolar tissue. They are found here because the capillary system is not distributed minutely enough to supply all parts of this tissue.

The white fibers of areolar tissue are arranged in a peculiar way. They are not in straight lines but are placed so as to form an irregular network. Neither do they run singly, but are arranged in bundles and have a wavy outline. When looking at them under the microscope, if one is unable to determine the

fact that they are arranged in bundles, he assumes that each individual outline is a single fiber and concludes that the white fibers are larger than the yellow. In reality while the bundles of white fibers form a larger mass than the single yellow fibers, the individual white ones are much smaller. These white fibers give to the areolar tissue its characteristic firmness and strength.

The yellow or elastic fibers are, as we have said, larger than the white. They differ also from the white fibers in that instead of having a wavy outline, they run in a straight course, branching and joining with one another, and thus forming a meshwork with straight regular sides. One should always remember that yellow fibers, no matter where found, are elastic in character, while the white fibers are those structures which give strength and support to the surrounding organs and are non-elastic.

Areolar tissue is arranged by Innate Intelligence below the surface of the skin, below the serous membranes, and below the mucous membranes, in order that it may offer itself as a strong supporting framework for the epithelial cells to rest upon. Remembering that the epithelial cells are possessed of a comparatively small amount of cementing material, there must be some way provided for them to be held together, and this is accomplished by the underlying membrane.

Innate also makes good use of the fact that the areolar is a loosely constructed, tough, strong membrane, and utilizes the spaces between the fibers and cells for the minute serous channels. The nearest approach that blood vessels make to the epithelial cells is as they lie in the areolar tissue, so Innate takes nutritive material from the serum which they contain and transports it through the interspaces of the areolar tissue to its final termination in the epithelial cells.

FIBROUS TISSUE

Fibrous tissue is one of the connective tissues which is found especially in those structures requiring great strength. This

strength is obtained because each individual white fiber runs parallel with every other fiber in the tissue, thus giving great strength in the longitudinal direction. Not only is this true of the fiber, but each individual cell, (and each fiber is formed of many cells) is arranged parallel to every other cell. In other words, a fiber is formed of a mass of cells arranged in one long regular chain. The chief characteristic of fibrous tissue being its strength, we must look for its location in those places where great strength is required, and we find it in the tendons and ligaments of the body, where they join bone to bone and muscle to bone, also in the periosteum, which acts as a protective covering, in the true skin, in the sclerotic coat of the eye, where a tough protective membrane is required, and in the dura mater which surrounds and gives protection to the brain and spinal cord.

Fibrous tissue has the function of offering itself as material to be used in those places where great strength is required, and as a covering for delicate structures which must be well protected from injury. Although fibrous tissue in most of its offices is a comparatively inactive tissue, still it must receive its mental impulses from Innate in order that its metabolism may be carried on, and it must be supplied with afferent nerves in order that Innate may be aware of any changes that take place in its structure.

In the periosteum we have a function of the fibrous tissue which is not expressed in that of any other location. Here we have Innate using the fibrous tissue as a place of origin for the osteoblasts, and continually they are being sent out into the bone forming new layers to take the place of the worn out old.

ELASTIC TISSUE

Elastic tissue is that connective tissue which, as the name implies, is elastic in character, and so it is that the yellow fibers predominate. The yellow fibers are arranged parallel with one

another, that is having the same general course, but widely branched and re-branched, and these yellow fibers are then bound into bundles by a limiting membrane of areolar tissue. We may have several of these bundles in a structure where elastic tissue is found. Having determined its function, we must necessarily look for its location in those places where a great deal of elasticity is required. We find elastic tissue composing the ligamentum subflava and ligamentum nuchae of the spine, in the coats of arteries and veins, in the coats of the lungs and air passages, and in the vocal cords. Of course, in the vocal cords elastic tissue has its importance in the fact that as it stretches or relaxes, a high or low tone is produced, but in ligaments and vessel coverings where it is found, the importance is in the fact that its elasticity takes off from the muscular tissue a great amount of strain.

The function of the elastic tissue is to offer itself for use in those places where much elasticity is required, and here is merely an instance of where the knowledge of Innate over the laws of physics is expressed. True it is that the vocal cords are only productive of sound when Innate expresses herself by altering the position and shape of the larynx, and it is equally true that the elasticity in the blood vessels is not utilized until Innate expresses herself in the contraction of the heart, but further than all this she has shown her wonderful mastery over developmental detail in placing all these tissues just where they can be utilized to the greatest advantage.

If it were not for the elasticity in the arteries they would be as solid tubes and instead of kinetic energy transforming itself to potential energy, and thus forcing the blood gradually through the capillaries, it would be sent through in spurts corresponding with each heart beat, and the tissues could not be properly supplied with oxygen.

ADIPOSE TISSUE

Adipose tissue or fatty tissue is one of the most common

of this group and is found in practically all parts of the body with the exception of the eyelids, the penis and the clitoris. It is developed usually much in the same way as is areolar tissue, but differs from it in that small oil globules are found in large quantities in the interspaces of adipose tissue. Upon microscopic examination, we find that each fat globule is approximately 1/400 to 1/500 of an inch in diameter, that the wall of each of these globules is formed by a mass of limiting protoplasm and that the oil or fat is contained in the center in the shape of a large oval mass forming the main bulk of the globule.

These globules are formed of the ordinary connective tissue varieties which have become filled on the inside with fat oil. It is true that they may be developed from any of the various types of connective tissue corpuscles; still the mast cells or granular cells are those which are most subjected to change, and it should be remembered further that these fat cells may be seen in various stages of development. At first there is comparatively a minute mass of oil in the center of the cell and this gradually enlarges and continues to enlarge until the fully developed corpuscle is present. Nutriment for the cell is received from a dense network of capillaries and lymph vessels which find their way between each individual fat corpuscle.

Now we come to the problem of the function of adipose tissue. In the first place we assign to it the function of acting as a reservoir of heat producing materials which may be used as necessity arises. It is also a non-conductor of heat, and its presence beneath the skin, covering practically the entire body, is for the purpose of maintaining the bodily temperature at a given degree and preventing all undue radiation. The third function assigned to it is to act as a shock absorber, and it is located in those places where it is most valuable in protecting soft and delicate parts. An example of this function is found in the orbital cavity, where it serves as a cushion and protection for the eyeball.

RETIFORM TISSUE

Retiform tissue is one which is so named because of the reticular shape of the interspaces which are found between its fibers. The fibers of retiform tissue are almost entirely white, and these white fibers are arranged in very small bundles which cross and recross, producing a dense network of the peculiar shape designated. Under ordinary examination by the microscope one is unable to determine that these fibers are arranged in bundles because each bundle is surrounded by a layer of areolar tissue which binds and holds the fibers together.

LYMPHOID TISSUE

There is only a slight difference between adenoid or lymphoid tissue and retiform tissue. The difference is that in the lymphoid we have great quantities of white corpuscles or lymphocytes which are constantly being formed and multiplied and as constantly are being washed out into the blood stream. Here, having undergone a process of growth, they are called leucocytes, although they are the same in structure as when contained in the lymphoid tissue. The fibers of retiform and lymphoid tissue are the same and the interspaces are the same, and the only difference is the presence of corpuscles in the lymphoid tissue and their absence in the retiform tissue.

The function of retiform tissue is to offer itself as a tissue admirably fitted for binding structures together, and yet of loose enough formation to allow large spaces for the passage of serum to those places where it is needed. This is illustrated in the lymph spaces of the lymphatic glands, where the more dense lymphoid tissue forming the main bulk of the gland is attached to the supporting framework by the retiform tissue, and thus the serous fluids are allowed free passage through the gland.

JELLY-LIKE TISSUE

Jelly-like connective tissue is just as the name implies, a form which is very soft in consistency and which is bounded and

held together by a more solid tissue such as areolar. For instance, in the eye we have the vitreous and the aqueous humor, both of which are characteristic jelly-like tissues, and if the surrounding membrane is taken away, soon settle into a shapeless mass. We may say that the jelly-like connective tissue is composed of an abundance of ground substance, while there are very few cells or fibers contained in its structure. Jelly-like tissue is found especially in the embryo and in the jelly-like substance which surrounds the blood vessels of the umbilical cord, separating them from the external tough membrane with which they would otherwise come in contact.

Jelly-like tissue is one of the most active of all the connective tissues, as it is present in the foetal body where changes are continually occurring and development is constantly taking place. Innate must therefore maintain a large supply of mental impulses to it in order that these processes may be normally carried on.

CHAPTER IV

CARTILAGE

In the study of cartilage, we find that histologically it is divided into two main divisions. The first of these is known as hyaline cartilage, the other as fibro cartilage. The latter may in turn be subdivided into two heads, one of which is known as white fibro cartilage and the other as yellow elastic fibro cartilage.

Hyaline cartilage is one wherein there are large quantities of tough intercellular material which hold the cells together, but is not permeated in any way by fibers, either of the white or the yellow variety. It is divided into four subdivisions, the first one of which is called articular cartilage, and is found, as the name implies, covering and directly adherent to the articular ends of bone, where it serves to eliminate to a great degree the friction of bone against bone.

The second division of hyaline cartilage is known as costal cartilage, and is so named because it is found forming the connection between the ribs and the sternum and in the ensiform appendix. Here it has the function of acting not only as a connection between the bones, but it acts as a protection to the softer parts of the viscera which are found below. Further than this it admits of a change in size and shape of the thoracic cavity, thus permitting breathing.

The respiratory cartilages constitute the third subdivision and are so named because they are found largely along the course of the respiratory tract. We have, as an example, the cartilages of the nose, we have those of the trachea and those of the bronchi;

also three of the principle cartilages of the larynx, namely, the thyroid, cricoid and the arytenoids.

The fourth division is known as the tempory cartilage because of the fact that it exists temporarily. It is composed of those cartilages which precede the formation of bone in the development of the body, and later become changed into bone.

White fibro cartilage may also be divided into four subdivisions. First, there are the inter-articular fibro cartilages which form pads between the articular ends of the bones. They differ from the articular cartilages in that articular cartilages are adherent to the bone as, for instance, in the knee. While they themselves do not come into direct contact they are found between the articular cartilages serving to protect them from excessive friction and to absorb shocks transmitted through the bones.

The second division is known as the circumferential cartilage, and is that type which is found at the margins of deep cavities, as, for instance, the glenoid cavity and the cotyloid cavity. Here we find the cartilage placed around the border of the depression, serving to deepen the socket and further to hold the head of the articulating bone in its position.

Third, we have the connecting cartilage, so named because of the fact that it connects bone to bone, and we have this type well illustrated in the intervertebral cartilages, in the cartilage of the pubes where they must withstand a great deal of weight and tension. Hence we have the presence of the white fibrous type.

Stratiform cartilage is the fourth division of the white fibrous group, and is found in grooves over which glide tendons and ligaments. It is sometimes developed in tendons themselves where the tendons must undergo much friction.

White fibrous cartilage consists of a matrix in the substance of which are found large quantities of cells and fibers. In fact, the intercellular ground substance here does not exceed

the cellular and fibrous structure as it does in the hyaline cartilage. Rather the matrix is exceeded by the fibrous and cellular elements. These fibers of the white fibro cartilage, while not parallel, all have the same general direction, and they are arranged in definite bundles which cross and recross one with another.

Yellow or elastic fibro cartilage is found in those places where strength is required and where elasticity must also be present. The cells of yellow fibro cartilage are usually round or oval, and between them we find quantities of ground substance. This ground substance is permeated by great masses of yellow fibers not arranged as in the white cartilage in a definite common direction, rather they extend in all directions, and are not arranged in bundles as in the white fibro cartilage. The yellow elastic type of cartilage is found in the epiglottis of the larynx, in the cornicula laryngis, in the cuneiform of the larnyx, in the pinna of the ear and in the eustachian tubes.

In regard to the general structure of cartilage we may say that the cells have around them a limiting membrane, that the cell divides into two. While the original limiting membrane still remains, each of the new cells forms another, and this process is repeated indefinitely until we have a large mass of cells and their limiting membranes form a large part of the intercullular matter of the matrix. It is thought that in the course of development this is one of the ways that the matrix is formed by the cellular elements, although it is by no means true that all of the ground substance is composed of limiting membrane.

The function of cartilage is to offer itself as a substance to be used where a certain degree of strength is required and yet where bone would be of too inelastic a nature. Such a condition we find in the cartilage which is known as the temporary type. Here cartilage occurs before the bone is formed, and during foetal life, where the child's body is necessarily contained in

a small space, and the long bones must lie in a curved position. Here elasticity is absolutely essential. In the articular and inter-articular circumferential and connecting cartilages, the substance must be compressible as well as elastic, and still strong enough to support weight and tension. Hence its function here is to provide itself as a suitable substance possessing these qualities.

Costal cartilages are placed between the ends of the first ten pair of ribs and the sternum, thus allowing for a variation in the size and shape of the thoracic cavity which could not be accomplished if the entire thorax were composed of bone.

CHAPTER V

BONE

Bone is the substance which is found very widely distributed throughout the entire body and it is this structure which tends to give shape and support to the softer parts contained.

Even though bone is a comparatively hard substance, it should be noted that it contains nearly 50 per cent of water, and that of the remaining portion, 33 per cent is animal matter and 67 per cent is mineral matter; the chief constituent of the latter being calcium phosphate. Of the animal matter the principle part is known as collagen, and it is a thick, sticky, cementing substance. There is a very close union of the animal with the mineral matter, and they are found intimately interwoven so that when the one is eliminated the other still retains the shape of the bone.

If one wishes to eliminate the animal matter in bone, it can be done by the application of intense heat. It will be found, upon examination, that the mineral matter which is left retains the former outline but the substance is brittle and easily broken. If one wishes to eliminate the mineral matter of the bone, it can be done by immersing the specimen in a strong concentrated acid. It will be found after this experiment has been performed that the bone, while retaining its original shape, size and contour, still is extremely soft, easily bent and often can be tied in a knot.

There are two main kinds of bone designated from the histological standpoint; one of these is known as the compact type and the other as the spongy type. We find this very nicely illustrated in making a longitudinal section of the head of the femur. To all external appearances, the femur has a

solid compact head, but upon section it is found that practically the entire cavity of the head is filled by a soft, cancellous, spongy bone structure. This spongy bone tissue is not found extending throughout the entire length of the bone shaft, but is present only at the extremities. We find this cancellous tissue also in flat bones; for instance, in the parietal bone and the scapula, where it forms a continuous spongy layer between the external and the internal hard plates. This intervening cancellous bone is known as the diploe.

Together with the two kinds of bone tissue, we should study the two kinds of marrow. They are red and yellow types.

Red marrow is that type which is always found filling the interspaces of the cancellous bony tissue and its red color is due to the fact that it is highly vascular. Thus it maintains the nutrition of the cancellous bony tissue. There are various kinds of cells found in the red marrow; the principle type of which are known as the marrow cells. These cells are present in large numbers, and it is from them the substance of the marrow is principally formed. There are also contained in the red marrow small nucleated cells, red in color, which are known as the erythroblasts, and it is from these cells that the red blood corpuscles are developed.

The other type of marrow, known as the yellow variety, is found filling the medullary canals of bones where the spongy tissue is not present. It contains also many large marrow cells, but these are not concerned in the production of red blood corpuscles. It differs from the red marrow in color partly because the erythroblasts are absent and partly because it is not so highly vascular.

Every bone in the human body is covered by a tough fibrous membrane which is known as the periosteum, and this periosteum is present on all surfaces of the bone with the exception of those which are in contact with other bones. Here the periosteum is substituted by the articular cartilage.

The periosteum plays a very important part in the nutrition of bone in that it is from the dense plexus of blood vessels found in this structure that the nutritive matters of the bone are derived. These blood vessels, very small in size, pass through small openings on the surface of the bone. They penetrate into the deep substance of the bony tissue and supply the spaces of the bone with nutritive matters, and these spaces, coming in direct contact with all the cellular elements, make it possible for every particle of bony tissue to be properly supplied.

HAVERSIAN SYSTEM

Upon examination, by the aid of the microscope, it is found that practically all bone has a distinctive structure. Upon longitudinal section of a long bone we find that there are many little canals running parallel with the medullary canal, but they are much smaller in size, being about 1/300 of an inch in diameter. They are known as the Haversian canals, so named because the physician, Dr. Havers, first gave an accurate description of them.

Around each one of these Haversian canals we find layer upon layer of compact bony tissue, and these are known as the Haversian lamellae. These Haversian lamellae are 8 to 15 in number. This arrangement is known as the Haversian system, and the structure of the bone contains a great number of these systems. Each one upon cross section is found to be round or oval; thus there are spaces between them to be filled and the lamellae with which they are joined are known as the interstitial lamellae. There is another kind of these lamellae known as the circumferential type, so called because they are arranged in a definite concentric outline exactly following the contour of the external surface of bone. These concentric lamellae may be 6 to 10 in number. They are found not only beneath the surface of bone, but are also present surrounding the medullary canal and conforming in shape to its outline.

Between the lamellae we find interspersed at various dis-

tances, little lacunae, and these lacunae are connected with one another by small channels known as canaliculi. In each of these is placed the body of a bone corpuscle, and extending out into the canaliculi are branches of the cell. The corpuscles do not entirely fill the spaces because they have been cut off from nutrition and died during the course of development, but it is their presence primarily which caused the spaces to be formed.

Each layer of compact bone is formed by fibers crossed and recrossed, forming a dense network, and they are named the intercrossing fibers of Sharpy. We have also what are known as the perforating fibers of Sharpy, which resemble in character ordinary white connective tissue fibers. They extend from the periosteum surrounding the bone into and perforating the circumferential lamellae, tending to hold these lamellae together and to form a firm attachment for the periosteum.

DEVELOPMENT OF BONE

It may be said that all bones are classed in two divisions, depending upon the way in which they are developed. First: We have that kind which is developed directly from a membrane such as the flat bones of the skull, the scapula, etc. Second: There is the development of bone upon the prefigurement of temporary cartilage, as in the humerus, in the femur and other long bones.

We will first consider the subject of ossification in membrane because it is the simpler form and the one upon which the cartilagenous ossification is based. The membrane from which bone originates, later becomes the periosteum, but it exists before the development of bone as merely a membranous sack consisting of an external and internal layer, with a space between, which space is the site of our future bone.

The external layer is of a tough fibrous character, as is any fibrous tissue, while the inner layer consists of a network of fibers, interspersed with osteoblasts and osteoclasts. These cells are of various shapes, some branched and some unbranched;

some oval and other irregular in shape. It is known as the vascular layer because it is more richly supplied with blood than is the fibrous.

Just before the process of ossification in membrane begins there is a great increase in the amount of blood which is sent to this vascular membrane, and it becomes thickened and more compact because of this fact. There is contained in about the center of the vascular membrane, a point which is spoken of as the center of ossification, and from this center of ossification there begins to grow small fibres exactly like those of fibrous tissue except that they are straighter and less wavy. They are termed the osteogenetic or bone forming fibres and are made up of a substance called osteogen.

After a layer of these projections has extended out from the center of ossification, there are deposited around them granules of calcerous matter, and these are deposited in great numbers, finally completely surrounding and enclosing the osteogenetic fibers; from this time on, they are recognized as the bony spicules of the network. It is these bony spicules which form, in later life, the intercrossing fibers of Sharpy which go to make up the lamellae of bone. During the same time that the osteogenetic fibers are being advanced, the osteoblasts are also being poured out from the same center of ossification, and as these osteoblasts are poured out in great numbers, they tend to deposit the materials used in the formation of bone. This process of depositing layers of fibers, osteoblasts and calcareous matter is continued until layer after layer is so deposited; each layer advances further and further toward the border of flat bone and finally the point is reached when the process of ossification discontinues.

The development, however, of the flat bones is not always complete at the time of birth; thus we have the presence of the fontanelles in the new-born babe. Their existence is due to the fact that the cranium at these points is completed merely by a

layer of membrane which has not as yet fulfilled its process of ossification.

The osteoclasts, after the development of bone has proceeded to a certain degree, are poured in from the center of ossification and tear down the inner part of the bony structure formed, thus leaving a layer of hard bone on the outside, also a layer of hard bone on the inside, but between these two layers there is destruction of bony tissue to such a degree that it remains only as cancellous bone. This cancellous bone becomes filled with red marrow and the layer is called the diploe.

The process of ossification in cartilage takes place in every long bone and is just as the name implies, a form wherein the bone is preceded by the formation of cartilage.

We will assume that the femur is being developed. We must bear in mind that the cartilage which prefigures the femur is much smaller than the future bone will be; even smaller than the medullary canal of this bone; consequently in the fully developed bony tissue of the femur there is no trace left of the cartilage which was first present. This cartilage is surrounded by a membrane which is known as the perichondrium and which later will become the periosteum of the bone. It is from this perichondrium that the long bone is to be formed.

We will divide the process of cartilaginous ossification into three stages. First: The cartilage cells in the center of the shaft become very much enlarged and toward either extremity they become arranged in definite lines. At this time there begins to be deposited in the cartilaginous shaft little calcareous particles which are tending to harden the structure which is present. At the same time that this change is going on in the cartilage the perichondrium is sending in from its centers (there are several centers of ossification) osteogenetic fibers, osteoblasts and calcareous matters, and forming layer upon layer of solid compact bony tissue just the same as are formed in the membranous ossification.

The osteoblasts become walled in by the process of calcifi-

cation and leave little spaces within which they themselves are hidden, and they are known from this time on as bone cells after they have been so imprisoned. During this period also the cartilage cells are being walled in by the calcification process going on in the cartilage. They are cut off from nutrition and waste away, leaving the small spaces in the cartilage which are known as the primary areolae.

Second stage: Immediately following this change, there is an eruption of the osteoblasts from the perichondrium out into the cartilage, and with these osteoblasts are many osteoclasts or bone destroyers. These latter cells immediately begin to tear down the calcareous deposit which has been built up in the cartilage and several of the primary areolae are thus joined, forming what are known as the secondary areolae.

These secondary areolae become larger and larger in size, forming the medullary spaces, and these medullary spaces all finally join forming the medullary canal of the long bone. However, the outer border of this destroyed cartilage is filled by layer after layer of direct bone which is deposited by the osteoblasts.

Third stage: Merely a continuation toward the extremities of the process which we have just described.

After birth the osteoblasts tear down slowly the compact bone which has been thus far formed, and immediately that an area is destroyed it is again replaced by compact bone which is in a regular lamellar form, and we have so constructed the Haversian systems. This tearing down process does not progress rapidly enough that the bone is materially weakened. We can see readily then that the formation of bone prefigured by cartilage, is nothing more than the same process which is carried on in membranous ossification. Every step in the former is present in the latter. The ossification which developes from the perichondrium in the one case corresponds exactly with the membranous ossification in the other, so far as the center of ossification is concerned. Both limiting membranes finally become the periosteum.

It would be as erroneous to assume that all this change which occurs either in intramembranous or intracartilaginous ossification is the result of accident, as to assume that the earth rotates upon its axis as it does, merely as a happenstance. There must be a controlling influence which governs the depositing of cells, which governs their destruction and finally which maintains the permanent by supplying them with the proper nutritive impulses, and anabolistic materials.

Bones are of many different shapes and perform many different functions. Long bones are placed in those locations where a great deal of action is required, and their ends are so constructed as to allow for the greatest possible amount of movement. Muscles are in turn fastened to these bones which under the direction of Innate Intelligence contract and produce all kinds of movement, such as adduction, abduction, flexion extension, circumduction and rotation.

Short bones are placed in those positions where Innate can best utilize them in producing powerful actions and withstanding unusual shock.

Flat bones are placed where they may offer themselves as hard substances for the protection of softer and more delicate organs. This is illustrated by the flat bones of the skull, which are placed in such a manner that they successfully protect the very soft and delicate brain substance.

Irregularly shaped bones are found placed by Innate in those locations where great weight must be borne, or where soft parts must be protected and the surrounding shell of bone must be irregular in shape to accomplish this end.

Strictly speaking there is little action in bone itself, and physiology is action. However, in the arrangement of the bones of the body, possibilities are given to them by Innate which mechanically illustrates in some measure the unlimited intelligence which this body is governed by, not only during life but immediately fecundation takes place and the ovum starts to develop.

CHAPTER VI

TEETH

There are, in the process of maturing, two sets of teeth, which make their appearance one before the other; the first set is called the milk teeth or the temporary teeth, and the second is called the permanent set. The temporary are five in number in each quarter, making in all twenty, and named from the middle line of the jaw outward to the side they are: two incisors, one canine and two temporary molars.

The incisors make their appearance first at about the sixth month of life and are followed by the first temporary molars, which make their appearance at about the first year. We have the canine teeth which make their appearance when the child is about one and one-half years old, and following these the eruption of the second molars when the child has reached the age of two years.

At about the sixth year of age, the permanent teeth begin to make their appearance, and if their site is occupied by temporary teeth, push them out in order to make place for themselves. The first molars are the ones which first appear at the sixth year of age, but they do not appear on the site of the temporary molars. They develop just posterior to the temporary molars, and thus do not destroy any of the temporary teeth. We have the eruption of the first incisors at the seventh year and of the lateral incisors at the eighth year on the sites of the former incisors. Following these the bicuspids make their appearance. The first bicuspids appear at the ninth year of age, crowding out the first molars of the temporary set and occupying their positions. The second bicuspids by their erup-

tion, crowd out the second temporary molars and thus the space of these two temporary teeth is occupied by the two bicuspid teeth of the permanent set. Following, we have the appearance of the canines on the former site of the temporary canines, and this appearance is made at about the eleventh year of life. The second molar teeth then appear, posterior to the first permanent molars and thus do not occupy the former position of any of the temporary teeth. There is then only the eruption of the third molars or wisdom teeth to follow, and this is accomplished by the eighteenth or twenty-fifth year. Sometimes it does not take place at all because of the lack of room behind the second molars.

It should be understood that these periods are only an average; that many individuals have their teeth at different times, some later and some earlier. Further, it should be remembered that some diseases effect the eruption of the teeth as, for instance, rickets.

The teeth are so placed in the two jaws that they, as sets, do not oppose each other; rather the upper incisors overlap the lower incisors, allowing for a scissor-like motion in biting food particles; also the upper bicuspids and molars are so placed that the upper set partly overlap the lower set, and thus they are capable of producing a grinding motion which is very important in breaking up and masticating food particles. Another fact which should be noted is that no two teeth directly oppose one another with the exception of the third molars. This is because the upper incisors are wider than the lower and the two central incisors in the upper jaw thus oppose, not only the two central incisors of the lower jaw but also in part the lateral. The lateral incisors of the upper jaw oppose not only the lateral incisors of the lower jaw but also a part of the canines. This eliminates the possibility of a tooth in one jaw becoming useless when its fellow in the opposite is gone.

Teeth are said to consist of three descriptive parts; the crown, the neck and the root. The crown is that portion which is visible and which is covered by hard white enamel. The neck is found just beneath the crown as a constricted portion, while the root is that part which extends downward into the bony tissues of the jaw.

There are three distinctive parts of which a tooth is composed. Histologically, they are known as the enamel, the dentine, and the pulp. In the study of the tooth pulp, we may say that it is that connective tissue which is found in the cavity of the tooth, a central space within its body, in which tissue are found cells, blood vessels and nerves. The nerves and blood vessels very richly supply the pulp cavity and the connective tissue thereof with quantities of blood and nutriment of oxygen and of mental impulses. The outer border of the pulp cavity is that portion which is directly in contact with the dentine of the tooth and is formed by a layer of odontoblasts, which have a very important part to play in the development of the tooth.

There is always a membrane which covers the tooth and through which it has to break before it makes its appearance above the gums, and this membrane is known as Nasmyth's membrane, or the cuticle.

The dentine of the tooth is similar to bone, except that it is much harder, containing only ten per cent of water, and of the remaining portion approximately seventy per cent is mineral matter. This mineral matter is made up chiefly of calcium phosphate, as is also true in bone. It is found upon microscopic examination that the pulp cavity directly communicates with the dentine by means of a system of extremely minute channels which extend perpendicularly to the surface of the tooth and through which it maintains its nutrition. Extending into these channels, we find prolongations of the odontoblasts, and it is here that the odontoblasts have deposited these projections during the time when they were developing the tooth.

The enamel upon microscopic examination is found to consist of little prisms approximately 1/5000 of an inch in diameter. These prisms are placed on the surface of the dentine and from there are arranged one above the other until the entire body of the enamel is formed. About two per cent of the enamel is composed of water and all the remaining ninety-eight per cent is mineral matter, thus making the enamel the hardest tissue in the body.

In the description of the tooth we should not omit the structure of the cementing material which binds the tooth in its socket. It is essentially a layer of connective tissue composed of bone, containing lacunae and canaliculi, and it is of such a structure that it tends to hold with the greatest tenacity the substance of the tooth in contact with the substance of the jaw bone.

DEVELOPMENT OF TEETH

The development of teeth begins in foetal life and has its primary origin in the thickening of the epithelial tissue over the embryonic jaw. This tissue thickens and begins to dip down in a continuous line along the course of the entire jaw and this downward growth extending along the entire length is known as the common enamel germ. From this common enamel germ there is a further downward growth on the site of each of the future teeth, and these downward projections are known as the special enamel germs, each one of which corresponds in position to the site of the tooth which is to be developed from it.

At this time there is a growth of the connective tissue below this special enamel germ which projects up into its body. It is known as the dental papilla and thus the shape of the enamel germ is changed from that of a sac, which is convex on all its sides, to that of a sheath which shows the contour of the dental papilla and is convex on its upper side and concave on its lower border. The dental sac is the name which is given to that part of the connective tissue which surrounds the enamel germ and is found between it and the osseous jaw.

We find that the dental papilla is formed of various kinds of cells, the principal ones of which form its outer layer and are known as the odontoblasts. This layer is directly in contact with the concave portion of the dental or the enamel germ.

At the time of beginning of the formation of dentine they deposit a layer of uncalcified matter at their distal extremities, which is called odomogen, and after having deposited this layer they retreat toward the center of the papilla. This first layer becomes calcified and hardened forming the first or external layer of the tissue, which in the future will be called the dentine. However, while the odontoblasts are retreating they are depositing another layer of the substance, and this process is kept up until layer after layer has been deposited and hardened and the entire body of the future dentine is formed. However, as the odontoblasts retire they deposit projections of their bodies in little tubular spaces, until finally their destination has been reached on the outer border of the pulp cavity. These projections remain in these small canals or tubules, and it is through them that the process of nutrition is carried on.

The enamel is formed in very much the same way as is the dentine. The inner layer of the epithelial tissue which forms the special dentine germ is made up of a mass of columnar cells, which are known as the adamantoblasts. Just external to this there are several layers of polyhedral nucleated cells forming what is known as the stratum medium. Then further toward the external there are other cells of various shapes and sizes, forming a large part of the bulk of the germ.

The adamantoblasts deposit in the first place a layer of keratin-like substance just next to the first layer deposited by the odontoblasts, and as their first layer is formed they retreat toward the external, depositing as they go, layer after layer of this keratin-like matter, which becomes harder and harder, undergoing calcification and finally the first of the enamel is so formed Retreating further, other layers are formed until finally the

adamantoblasts are approaching very close to the external and becoming extremely short, until they disappear, and the tooth emerges through the cuticle and to the external.

The dental sac at its lower part where it is opposed to the root, forms the substance known as cement, which has the function of binding the tooth in its socket.

The second set of teeth is formed in the same way as the first. The special enamel germ gives off from the neck of the primary dental germ a projection, and this projection extends downward and under the temporary tooth, lying dormant in this position until the period for its eruption arrives. At that time it begins to expand, forcing out of position the temporary teeth and finally making its appearance on the surface of the gum. The three molars of the permanent set are developed from projections given off from the neck of the second temporary molar, so it can be seen that there are in reality four teeth developed from the dental germ of the original second temporary molar.

The function of the teeth is to break down the food particles which are taken into the mouth before they are passed on to the stomach and undergo gastric digestion. This, in reality, is not an action of the teeth, but rather the expressing of Innate Intelligence in contracting the muscles of mastication. When this is done the teeth of the upper set are brought into contact with the teeth of the lower set and, the tongue having been utilized in placing the food between the teeth, it is broken up in this manner into small and smaller particles until it is finally ready for deglutition. The construction of the teeth is admirably adapted for this action. In the front we have the incisors which are sharp and come to a knife-blade edge, but instead of the edges of one set coming in contact with the edges of the other, the upper teeth come anterior to the lower, and thus a scissor-like action is produced. The bicuspid and molar teeth are also well adapted for their particular duty, being of such shape that the food may be ground between the two sets and thus more readily broken up.

CHAPTER VII

MUSCLE

Muscle is the name given to one of the four elementary tissues in the body and is the structure by which motion is accomplished.

We may divide it into two main divisions from a physiological standpoint. The first division is known as the educated voluntary muscle, the second as Innate voluntary. The former is the type of muscle which acts by means of the power derived from Innate Intelligence, but which is guided in its action by the educated mind. The latter is that type of muscle which acts from the power and direction of the Innate Intelligence, without the direction of the educated mind.

Upon examination it is found that muscle tissue is composed of muscle fibers which are long, thin columns, bound together by connective tissue and with a definite and distinct arrangement which will be described later.

The muscle fibers from the histological standpoint may be divided into two main divisions; the first of which is designated by transverse lines of alternate light and dark character, which are seen traversing its structure, and this type is spoken of as the striated muscle tissue.

Found distinct from the striated muscle there exists the plain, which is composed of long fibers without the transverse stripes, and hence called the plain muscle fibers.

Striated muscle fibers compose those muscles which are educated in their function, while the plain type is found existing in those muscles which are Innate in their action. This is true with

the exception of the heart muscle, which is of the mixed variety and at the same time is Innate in function.

There is one peculiarity of muscle tissue which distinguishes it from tissues which we have heretofore studied. In the connective tissue we found that the fibers were placed between the cells, forming a part of the framework and supporting structure, the interspaces of which were filled by matrix; here on the other hand, the cells and the fibers are one in that the fibers are elongated cells.

The muscles under the control of educated intelligence are often classed as the skeletal muscles, in that they are found attached to the skeleton and produce the voluntary movements of the body.

They are composed, as we have said, of fibers, and the fibers are usually about 1/500 of an inch in diameter and one inch long. They are as a rule blunt at the ends and are continuous with other muscle fibers or with tendons which attach the muscle to bone. As a rule they are not branched, but this is not invariably true. In some parts of the body they branch and rebranch very much as small terminal vessels.

The fibers are surrounded by a sheath which is known as the sarcolemma, and within this membrane we have a softer substance which is called the matrix. The sarcolemma is a very tough elastic membrane whose function it is to hold the softer structures in place.

Upon examination under the microscope this fibre is found to be made up of alternate layers of light and dark transverse stripes throughout its entire length. Upon more minute examination, it is found that at the two extremities of the light layer, rows of granules are found, and uniting these rows are little dark lines which pass through the dark streaks. These little granules are also united side by side, by other little lines, making a dense meshwork throughout the entire cross-section of the muscle fiber. This meshwork or supporting frame is called the sarco-

plasm, and consists of protoplasm, which is slightly more compact than are the columns which are found in its interspaces. The sarcoplasm is to the muscle fibre what the spongioplasm is to the elementary cell. Between these walls of sarcoplasm which we have described, there are columns of softer tissue which are called the sarcostyles.

Upon cross section these sarcostyles look like irregular areas which are divided by the dense network of sarcoplasm, and these spaces between the fibers of the sarcoplasm are called the areas of Cohnheim. Upon minute examination of the sarcostyle, we find that it is divided longitudinally into sections which are spoken of as sarcomeres, and these sarcomeres are formed by a small dividing line which is known as the membrane of Krause. This membrane of Krause is found dividing each one of the light spaces of a muscle fiber, so that each membrane of Krause is in each of the fibres and at the same level. This sarcomere has at its center another line which divides it into two equal parts. This line is known as the line of Hensen.

Extending out from the line of Hensen toward the membrane of Krause, as the center of the sarcomere, we have tubules of a dark character, and it is the aggregation of these tubules, arranged next to one another that gives the characteristic dark and light stripes to the fiber. These tubules are made of a dark substance which is known as the sarcous element.

There is a peculiar feature in regard to muscle fiber which is striated in character and it is that the striations alter in shades as contraction or relaxation takes place. While the muscle is relaxed, the dark lines are present opposite the sarcous element, which is midway between the two membranes of Krause. During contraction, however, the space opposite the membrane of Krause becomes darker in proportion. This may be explained as follows: The sarcoplasm which is found surrounding each sarcostyle as a membrane, is caused to gather in folds at the membrane of Krause, because upon contraction, the sarcostyle at the line of

Hensen becomes thick, while that part near the membrane of Krause maintains its original size. The explanation for this change is simple. These small tubules in the sarcous element, when contraction takes place, are found to become filled with the clear fluid structure, which is found between them and the membrane of Krause. This necessarily will make them wider, while it will make the entire sarcomere shorter. It is also interesting to note this fact in regard to the contraction of muscle. It is due to protoplasm running into and out from these tubules. This harmonizes the muscular action, with the idea that ciliary motion is due to the passing of protoplasm into and out of the cilia, and is the factor which causes the characteristic ciliary motion.

We have so far considered only the elementary unit of muscular tissue.

We might say at this time that muscle fibers are bound together into bundles which are known as fasciculi by a cementing material known as endomysium, and these fasciculi are covered by a fibrous sheath, which is known as the perimysium. These bundles have between them, and surrounding them, binding several bundles into one common mass, a sheath which is known as the epimysium. The muscle tissue is supplied richly with blood vessels; the arteries breaking up and dividing into capillaries which extend logitudinally with the muscle fibres, and from which they obtain their oxygen and part of their nutritive materials. We will consider at a later period the termination of the nerve fibers in muscle.

Cardiac muscle is the tissue which is found forming the great bulk of the heart. The fibres are striated, but they are smaller in size than those of the ordinary striated muscles. The fibres are not surrounded by a sarcolemma, but are joined by transverse extensions to those fibres which lie parallel to them. They are shorter also than the ordinary striated muscle fibre. The difference physiologically between the cardiac and striated muscle is that the former contracts under the control of Innate Intelligence while the latter contracts under the control of educated intelligence.

CHAPTER VIII

ADAPTABILITY, CONTRACTILITY AND RHYTHMICALITY

Before we are able to study the various changes which occur in the muscle tissue upon experiment, we must acquaint ourselves with some of the terms used and the meanings of them.

Adaptability is that quality of an organism which causes it to undergo some change upon the application of an external vibration. Adaptability exists in some form in every tissue of the body, but those tissues which may be studied are nerves, secreting cells, and muscles. In nerves we have a response to a vibration, proven not by observing the change in the nerve itself, but by noting the action of the tissue to which it passes. In the case of efferent motor nerves, if the trunk is subjected to vibrations, there is an action in the form of contraction of the muscle which it supplies, while if the periphery of an afferent sensory nerve is so treated, there is, as the result, a sensation registered.

In the case of the epithelial secreting cells it is noted that a secretion is formed when the efferent nerves supplying this part are subjected to vibrations.

Contractility is the ability of a tissue to respond to an outside vibration by a change in its form, and while all tissues possessed of contractility are adaptable, not all that are adaptable are contractile. In the case of muscle we have a tissue which does respond to an external vibration by a change in its shape, and, therefore, is both contractile and adaptable. A nerve, however, while it shows from experiments that it is susceptible to vibrations because of the change which may be produced in the organ at its

periphery, does not show any change in its form upon stimulation, therefore indicating that while it is adaptable it is not contractile.

Contractility in ciliated epithelium is readily studied under the microscope, showing that the individual cilia under excitation are constantly changing shape. The individual cilia first is bent over toward its base on the cell, and shortly after is found to be straight projecting from the cell like a thin, upright spine. This change is accomplished by the protoplasm of the cell changing its position within the cell wall, first flowing up into the cilia, increasing the pressure in it and causing it to straighten, and then receding into the body of the cell and lowering the pressure in the projection, allowing it to sag back to its original position.

Contractility in the amoeba is noted upon the application of vibrations, in that projections (pseudo-podia) of the cell are extended in various directions, then withdrawn and other projections (pseudo-podia) extended in other directions. This change in shape is caused by the variations in pressure in the protoplasm of the cell, which change the outline of the enveloping wall.

Contractility of muscle is the phase in which we are most interested, because it is by the contraction of the muscles that the movements are produced. When subjected to vibrations the muscle contracts, because each individual segment (sarcomere) of a muscle fibril shortens. These segments shorten because the hyaloplasm of the sarcomere passes into the little tubes existant in the sarcous element, thus widening and shortening the sarcomere.

It will be noted in all of these examples that the same change takes place in the one as in the other, namely, that the hyaloplasm of the cell changes its position in the spongioplasm, thus producing the contraction.

Rhythmicality is the term applied to regular contractions or changes occurring at certain definite intervals. This idea is especially well illustrated in the muscle tissue of the heart, where we

have alternate contraction and relaxation occurring at definite regular periods. Is this contraction, occurring as it does, alternately, due to alternations in the timing of the impulses supplying the heart, or is it due to the peculiar ability of either the muscle or nerve to store up the potential energy transmitted to it in the form of mental impulses, until such a time as enough has accumulated to make it possible for a contraction to occur and thus change the potential energy to kinetic energy in the work of the heart muscle? Experiments have led to the conclusion that the latter view is correct, and that the rhythmicality of a muscle or other tissue is due to the storing up of the electrical impulse until a sufficient quantity has been received to do the required work. Further, the question has presented itself as to whether the rhythmicality of the tissue was an inherent quality of the tissue itself or was due to the character of the nerve or end plate with which the structure was supplied. Experiments here have led to the conclusion that the property is an inherent quality of the tissue itself and not of the nerve in any of its parts. However, this fact must not be lost sight of, that because the experiments which are performed on dead material, and are the result of electrical stimuli, seem to indicate certain features, it is no conclusive proof that the same would follow in the living man. Too often has this purely experimental basis in dead material been used as proof that physiological activity, exactly corresponding to it occurs in the living unit, and it has been left to the more recent investigators to question the truth of this hypothesis. There can be no question but that experiment upon prepared specimens of various tissues have led to many important physiological discoveries, but the conclusive proof of those discoveries must lie finally in the deductions made from observations of the living tissue. Bearing this in mind, it would hardly be wise to state that because the rhythmicality in the heart muscle preparation seems to be independent of the manner in which the stimulation is applied, that in the human body this is also true. On the other hand, it

seems to be a fact that the rhythmicality of the heart contractions in man, is directly under the control of the Innate Intelligence through the nervous system.

Stimulus is the term used to indicate the factor which causes muscular contraction when used in connection with experimental muscle changes. There are three kinds of stimulation which may be used to advantage in experiments with muscle preparations. These are:

Chemical stimulation produced by applying certain substances to either the muscle or the nerve leading to it, and producing a change in the muscle, due to the chemical composition of the applied substance.

Mechanical stimulation under which we may include the effect of pressure, light, heat, etc.

Electrical stimulation which is produced either directly or indirectly by the application of an electric current.

Any of these different forms of stimuli may be produced either upon the muscle preparation which is being studied, and this is known as direct stimulation, or it may be produced through the nerve which supplies the specimen and in this event it is known as indirect stimulation.

While it is true that these are varieties of the stimuli which may be used in experimenting with muscle preparations, it does not include that all-important impulse which we are essentially interested in, namely, the mental impulse. This is well illustrated in the occasion when the hand comes into contact with something which may prove damaging to the tissue or may perhaps be painful. In this event the sensory vibration passes along the course of the afferent sensory nerve and causes a thought, either objective or subjective, and as a result of this mental action the muscles which control the position of the hand remove it from danger. Here the muscular action is again the result of a mental impulse which starts on its course along the efferent nerve from the brain and upon reaching the muscle, causes the contraction.

This brings to our mind the question as to whether or not the impulse in itself causes the contraction. The impulse does not become changed in the muscle to a muscular impulse, but rather offers itself as a means of liberating the potential energy which is at all times existant, and allowing it to become at once kinetic energy. As is the case in turning the tap on a water faucet, we do not produce the flow of water any further than that we offer a means whereby the potential energy, expressed by the elevation of the water in the reservoir, may assert itself by flowing through the lumen of the tap.

Muscular changes upon contraction are:

1. Change in form, wherein the muscle becomes broader and shorter than when in the relaxed condition, being approximately three-fourths its length when at rest.

2. The extensibility of the muscle is increased upon contraction.

3. The elasticity is decreased upon contraction.

4. The temperature of muscle while contraction is taking place is increased because of the movement.

5. The electrical response of a contracted muscle is different than that of the muscle at rest.

6. The waste materials are given off more rapidly and nutritive materials consumed more rapidly in the contracted muscle.

CHAPTER IX

TIME ELEMENT IN MUSCULAR CONTRACTION

Before starting this chapter dealing with the experiments upon muscle preparations, it is well that we devote a paragraph in explaining the terms as used in order that the student may avoid confusion.

Stimulus is the term used generally to indicate the exciting agent in producing any activity either in the living specimen or in the preparation. It is, however, our intention to make a distinction in these two cases. When speaking of the exciting agent in connection with a prepared specimen, we shall use the term stimulus, and in dealing with the natural living unit, we shall use the term vibration or impulse.

Irritability is the term used generally to indicate the property of excitability either in the living specimen or in the preparation. Here, too, we make a distinction between the two states. In the natural living unit we shall speak of this quality as responsiveness, while in the preparation it shall be called irritability.

The record of contraction of the muscle is produced by a small instrument called a myograph, and the record which it makes is known as the myogram. The study of the myogram and the experimentation which leads up to its production is called myography.

The myograph is a very delicate instrument, so named because it is used in studying the muscular contractions, and so constructed that it records the slightest alteration in the shape of the muscle being studied. It consists of a cylinder, around the outside of which is wound a recording paper, while in contact with this sheet is the point of a needle which leaves an impression

wherever it touches. With this arrangement, the cylinder is started to rotate at a given rate of speed so that the change in the muscle may be studied not only as regards the changes themselves, but the length of time that is consumed during each alteration. Attached to the lever upon which is placed the writing needle is one end of the muscle preparation to be experimented with, while the other end of the muscle is stationary. It is unnecessary to go further into the construction of the myograph (there are many types of them) and we will continue with the results which are attained by its use. These results are, of course, the interpretation of the myogram.

When the muscle is stimulated by a single electrical impulse, the record written by the recording needle is known as a simple muscle curve, and shows several interesting points of observation.

The latent period is that time which elapses between the application of the stimulus and the beginning of the musclar contraction. Some of this period is consumed by the resistance offered by the myograph, some of it by the time consumed by the impulse in traversing the nerve to the muscle, but after due allowances have been made for these losses, it is still found that the latent period is approximately 1/400 of a second. This, however, varies somewhat, the latent period decreasing as the stimulus becomes greater.

The period of contraction is that period from the beginning of the contraction after the latent period until the muscle curve has reached its maximum. In the beginning, for about the first 1/200 of a second the contraction is not so rapid, but from this time on it rises rapidly until near the limit of its contractility, when it again slows down just before it reaches the maximum. This period of contraction lasts a trifle more than 1/20 of a second.

The period of relaxation constitutes that time in which the muscle is returning again to a state of rest. At first it relaxes slowly, but after about 1/200 of a second, the relaxation is rapid

until finally the stage of complete relaxation is reached. This period of relaxation lasts a trifle less than 1/20 of a second. It can readily be seen then that the entire period occupied during the contraction and relaxation of a muscle is about 1/10 of a second.

Variations of stimuli produce marked alterations in the extent to which the muscle preparation will contract. A very weak stimulus may be applied which will produce no appreciable change in the muscle preparation. If this stimulus is gradually increased, there will come a degree where the muscle is seen to respond ever so slightly and this degree is known as the minimum stimulus. Now, if the exciting factor is increased, it is found that the degree of contraction increases in proportion, until a limit is reached, above which no single stimulus will cause the muscle to contract. This is called the maximum stimulus.

The resistance to a stimulus causes a change in the myogram, in that as the load becomes heavier, against which the muscle is pulling, the contraction becomes less, until finally a point is reached when the load is so heavy that it cannot be lifted by the muscle.

Fatigue produces a marked change in the record of the myograph, in that if a muscle preparation is caused to contract time after time by the application of successive stimuli, a period finally occurs when the muscle does not return to rest between the stimuli, but remains continually in a state of contraction. At the beginning of the successive contractions, however, they become stronger and stronger, and this condition is known as the beneficial effect of contraction. Following this, however, the latent period begins to lengthen after the application of each stimulus, the contraction is not so great nor does it occur so rapidly, and the period of relaxation is very materially increased. This increase in the relaxation period continues to grow longer until a time is reached wherein the muscle is not entirely at rest by the time the next stimulus is applied and this condition is

known as contracture. If after this, there are still stimuli applied at stated intervals, the contracture passes off and the period of relaxation becomes less, but this is very largely accounted for by the fact that the contraction is materially decreased.

Temperature affects the contraction of muscle tissue as well as the other conditions which we have mentioned before. Cold has the effect of increasing the degree of the contraction for a short time, but after this the degree is less and the length of time occupied in the latent period, contraction period and relaxation period is lengthened, producing practically the same effect that is produced by fatigue. Up to 42 degrees C. the addition of heat increases the degree of contraction and shortens the period of contraction and relaxation.

The wave of contraction which proceeds in a muscle preparation upon stimulation is in a definite direction and of a definite rate of speed. This wave always proceeds from the point of entrance of the nerve into the preparation, to the extremities of the muscle. If the stimulation is made directly to the substance of the muscle itself, then the wave proceeds from the point of stimulation to the extremities. The rate of speed of this contraction can be recorded by attaching two light pincers one at either end of the specimen, and attaching to them levers, both of which rest on a revolving cylinder. When the wave of contraction starts at one end and proceeds toward the other, it spreads the light pincers which are placed upon them, and they in turn cause the recording levers to move, thus indicating the time at which contraction occurs. When the second lever is caused to move because of the spreading of the pincers attached to it, the cylinder will have revolved a certain distance. By timing the distance which the cylinder moves in a given length of time we are thus enabled to compute the time occupied in the muscle wave traveling from one end of the muscle to the other, and then in measuring the length of the muscle used, the computation of the rate of the muscle impulse may be made. Experiments have shown that this

is about three yards per second, although there may be some variation in this, due to heat, cold, fatigue, etc. The muscle wave always traverses slower as the temperature lowers, and as fatigue increases.

When two successive stimuli are applied to a muscle preparation, the second being at a long enough period after the first to allow the muscle to relax completely, there are two simple curves written upon the myogram. If, however, the second stimulus is applied during the relaxation period of the first, there is a second contraction, appearing before the relaxation is complete. This second stimulus, if of the same length as the first, and if the first was not a maximum stimulus, raises the contraction of the second stimulus higher than the first. If the second stimulus is applied during the latent period of the first, then there is no period of relaxation until the second has produced its period of contraction. Providing the sum total of the two stimuli is not enough to produce the maximum stimulus, the curve is a simple muscle curve, but greater than that which would be produced by either stimulus alone. This condition is the summation of stimuli.

When more than two successive stimuli are applied the effect is merely a continuation of that seen in the application of only two. If the stimuli are applied far enough apart that the muscle has time to relax between applications, we have merely a series of simple muscle curves, showing the beneficial effect of contraction. If, however, the second stimulus is applied before the period of relaxation of the first is finished, then the effect of the second is superimposed upon the remaining contraction from the first stimulus, and the application of the third and fourth are superimposed upon the effects of the others. As a maximum stimulus is approached, the individual contractions, superimposed upon those having gone before, become less and less, until finally the maximum stimulus is reached and the record made, shows the apex of each curve to be of the same height. This is providing the stimuli are applied far enough apart to allow for some relaxation. If the

stimuli are applied so close together that a continuous straight line is recorded, at the height of the maximum, then we have the condition known as complete tetanus. If, however, there are waves in the record, showing that the muscle does relax somewhat, we have the condition known as imperfect tetanus. The rate at which the stimuli must be applied to produce complete tetanus is determined largely by the type of muscle, what part of the body it is taken from and in what animal it is found.

MUSCULAR CONTRACTION IN MAN

These experiments just mentioned may be very largely substantiated by experiments in man. This is the fact which makes them important. The experiments, if they could not be associated with the living human unit, would not be of such great practical importance from a physiological standpoint. In brief, we are not willing to state that experiment on preparations is of no value whatever, but it can hardly be used as conclusive proof unless substantiated by further experiment in man.

The data accumulated in the last few pages must inevitably lead up to the action of muscle upon contraction in man, or it is of no value. First, we have determined that a simple muscular curve, caused by a single stimulation, lasts one-tenth of a second. We know that muscular contractions in man last a much longer period of time and the question naturally arises as to whether this is due to a number of successive mental impulses or to one impulse applied for a longer period of time. The answer is found upon observing the action of muscular tissue in man by means of a small instrument, known as the transmission myograph. By means of this apparatus we are enabled to determine that when a muscle of the body, such as the biceps is in a state of contraction, that this contraction corresponds to the incomplete tetanus just described, in that instead of maintaining a given state of contraction, it vibrates, these vibrations causing to be written a series of waves corresponding to those produced in incomplete

tetanus. These contractions occur at the rate of about ten per minute, but here we meet the obstacle that as each contraction and relaxation in experimenting occurs in one-tenth of a second, the muscle would have time to completely contract and relax ten times in the second. The explanation for this is that the mental impulse which causes the muscle to contract in the living body must materially differ from the electrical stimulus which is applied in experiments. In brief the mental impulse is of such a character that it produces and maintains the contraction longer than the electrical stimulus, and so vital impulses sent from the brain cell at the rate of ten per second, produce an incomplete tetanus, while if mechanical or electrical stimuli were applied that slowly in experimenting the result would be a series of simple muscle curves. In experimenting it is a peculiar fact that, no matter how strong the stimulus applied, which will produce an impulse from the nerve cell, the mental impulses will be sent out at just the given rate of speed. This conclusion is arrived at by excising one end of the gastrocnemius of a frog and attaching it to a writing lever. Now, if the sciatic nerve of the leg is stimulated, it being a sensory nerve, an afferent impression is carried to the brain, where it is interpreted. As a result of this interpretation impulses are sent out to the motor nerve of the gastrocnemius (still attached) and it contracts. This contraction, however, is the result of a series of impulses sent from the nerve center in the brain, at a certain definite rate. This fact is determined by the use of the recording myograph, and it makes no difference how strong the stimulus on the sciatic nerve, this rate is always the same.

CHAPTER X

EXTENSIBILITY, ELASTICITY AND ELECTRICAL VARIATION IN MUSCLE

Extensibility is a term used to indicate the change, which may occur in any substance by the material of which it is composed, becoming lengthened, and the degree of extensibility depends upon the degree to which it may be stretched without breaking.

Elasticity is the term used to indicate the power possessed by a tissue of returning to its normal position after having been changed from the normal. The two terms, extensible and elastic, are not synonymous. A piece of dough is very extensible, and yet when the force used to stretch it is removed, it will not return to its original shape. Rubber, on the other hand, is not only extensible, but when the stretching weight is removed from it, it immediately returns to its normal position. If a material is able to return to the exact shape which it possessed before the stretching force was applied, it is said to be perfectly elastic. If, however, it tends to return to its former position, but does not quite reach this state, it is said to be imperfectly elastic.

If a material offers a great deal of resistance to any force which would stretch it from its original position, it is strongly elastic. If, on the other hand, it offers little resistance to this force, it is said to be feebly elastic.

Steel is strongly elastic in that it requires a strong force to overcome the resistance in the material in producing extension. Muscle is feebly elastic because it offers no great degree of resistance to weight, which would stretch it from its normal position.

In experiments with muscle preparations a number of interesting facts are discovered. If a weight is applied on one end of the muscle, the other being stationary, the result is a stretched muscle. If more weight is added the extension becomes greater and greater. If now these weights are removed a little at a time the result is a gradual restoration of the muscle to its former position, until when all the weight has been disposed of the muscle is completely at rest. Experiments also point to the fact that when a muscle is in a state of contraction it is more extensible than when at rest. By placing a weight on the end of a muscle which has a length of five inches, and then stimulating the muscle to contract, the length becomes only four and one-half inches, thus the weight has been raised one-half an inch. If now, a greater weight is added, the contraction will not be as much as one-half inch, and finally a point will be reached when the weight will be just great enough that the muscle is unable to shorten at all. Thus, we have reached a condition when, although the stimulus has been applied, and the muscle has tended to contract, still it does not change position. There is a change, however, in the heat produced, in the chemical composition, etc., and it should be remembered that in contraction a shortening in the muscle is by no means the only important change existing. As a protective feature the muscle which is in a state of contraction, but which has met a weight which it cannot overcome, is very extensible, and this prevents the rupturing of its body.

Muscular tonicity is the condition in which all healthy muscles are found, and indicates a certain degree of contraction. These muscles are not contracted to such a degree that they are stretched, but enough that when they contract they will exert a direct pull upon their attachments instead of first taking up the slack which might otherwise exist in them. The tonicity of the muscle is maintained by the control of the Innate Intelligence, sending impulses continually to all parts of the body to keep the tissues in a healthy state. Those which pass to the muscles are

motor impulses, and are necessary to maintain the healthy state. Of course it must be admitted that in muscle, as in other tissues, other conditions must be favorable in order to maintain health, namely, the proper supply of oxygen, nutrition, and the proper secretions which are essential in destroying poisons, carrying them away, or neutralizing their ill effects. But one distinctive feature stands out in this connection, and that is that the proper nutritive materials and the proper distribution of them depend upon the coördination of those organs which have to do with digestion, absorption and assimilation. The proper amount of oxygen, and the distribution of it, depend upon the coördination of the respiratory system and the vascular system. The proper secretions to eliminate poisons depend for their action upon the coördination of the glands which secrete them. All of these organs depend for their coördination upon the action of the nervous system in transmitting impulses to them in order that they may utilize their ability to the fullest.

Early investigators were at a loss to know whether or not there was any electrical current generated in the muscle tissue itself. Some noted authorities claimed that muscle did produce an electrical current and some claimed that this was impossible. For many years the question was undecided, but finally experiments led to the conclusion that there was an electrical impulse generated by muscle. This has been determined largely by the use of the galvanometer, which is a very delicate instrument used to indicate the passage of a current over a wire, and to determine in which direction this current is passing.

By its use it has been found that if a muscle is cut at one end and a wire with a galvanometer is placed between the cut end and the uninjured longitudinal side, a current passes from the uninjured side to the injured end and from here to the center of the muscle preparation. The cut end is known as positive because the current flows into it from the galvanometer, and the uninjured lateral surface is known as the negative because it is

from here that the current returns to the galvanometer. At first it was supposed that this current was a natural one and existed at all times, but later investigations have shown that in the normal, uinjured muscle there is no electrical variation whatsoever, as long as the muscle is at rest, and that the variation just referred to is the result of the muscle being injured. If, now, the muscle is thrown into a state of continued contraction, the current, instead of flowing from the side of the muscle to the cut end, shows no variation and the galvanometer returns completely to rest.

It is our purpose to explain, however, the electrical variation of muscle during contraction, so we will first take up the experiment dealing with a single impulse to one end of an uninjured muscle and the resultant single twitch.

If a muscle has attached to its two extremities the two ends of the galvanometer to indicate the existence of a current and the direction of it and a stimulus is applied at one end which produces a single twitch, the following observation may be made: The muscle contracts in the regular muscle wave, progressing from the end of stimulation to the opposite end, but just preceding this wave of contraction there is an electrical variation in the muscle which is plainly indicated by the galvanometer. At the galvanometer wire nearest the end of stimulation, as this impulse progresses, a positive pole is established and the galvanometer shows a current traveling from the opposite point of attachment to it. Now, while the current is progressing from this first point of attachment to the second there is no indication of a current whatever, but when the impulse reaches the second point it becomes the positive pole and the current flows from the first point of attachment to it. This feature, shown by this experiment, is important in that immediately preceding each muscle wave contraction an electrical impulse travels, usually occurring about one-two-hundred and fiftieth of a second before the contraction itself. This change in the electrical condition is known as diphasic,

because the current travels in two different directions. If the muscle, however, is injured at one end and the second terminal of the galvanometer is attached to this injured part, the change is monophasic, because while the first point of attachment shows a positive pole upon contraction, the second attachment cannot show this change. This, because of the fact that the injured end cannot respond to the stimulus, and so the electrical response is also destroyed.

From these past observations it is easy to understand what occurs when a single impulse is used and a single twitch results, but the tetanizing series of shocks when applied produce somewhat of a different conclusion.

Where a muscle is used, one end of which has been injured, we have merely a series of monophasic alterations. The effect of one is superimposed upon the other and the center of the muscle thus has its positive character increased until the potential difference between the center and the cut extremity is decreased to the minimum.

If, however, an uninjured muscle is used, and the poles of the galvanometer attached to each end of it, and stimuli applied which cause waves of electrical variation, it would be supposed that the variation at the first point of attachment would be the same as that at the second point of attachment. In the experiments with the excised muscle, however, this is not true, because the strength of the excitatory impulse becomes less and less as it approaches the opposite extremity, and so the degree of positivity at the first pole is greater than that at the second, and as a result of this, the galvanometer shows the progression of a current from the last point of attachment to the first.

The question naturally arises as to whether these same conditions exist in the living subject under normal conditions. This is a matter which is open to dispute, first because of the fact that the prepared specimen is not possessed of life as is the tissue of the living body, and secondly, because there is no proof that the

electrical impulse which is applied as a stimulus is the same, or may be favorably compared with the mental impulse. With these two vital distinctions it is open to serious question whether these experiments in themselves may be offered as an argument that the same condition prevails in life.

CHAPTER XI

FATIGUE, CHEMICAL COMPOSITION AND RIGOR MORTIS IN MUSCLE

When there is contraction of muscle tissue there is a certain amount of work performed and the potential energy that is existent in muscle is transformed into kinetic energy. This kinetic energy expresses itself in the two forms of motion; namely, molar motion and molecular motion. The former is that form of motion where a mass changes its position and the latter where the molecules undergo a change in position and structures. Molar motion may be transformed into molecular motion, which is heat. This is well illustrated in bending a wire rapidly for a number of times; the molar motion is thus transferred into molecular motion and thus the temperature is raised. All heat then is the result of application of energy, and it may be also stated that all work done is the result of energy applied.

Using this, then, as our basis, we find by experiment that when a muscle contracts it does so because of the liberation of energy, and this energy is transformed during the action into two forms. One of them is the work done and the other is the increase in temperature. More energy is used, however, in raising the temperature of the muscle than is used in the accomplishment of the work. Further, the work, if done in a few strenuous contractions, produces more heat than if done in a number of short contractions. This is evidenced by the fact that if one lifts a weight by a pulley to a certain height in several long pulls, he is more fatigued than if he had lifted the same weight the same distance by short pulls. Fatigue varies in the same proportion as heat, because they are both dependent upon chemical decomposition in the muscle.

The thermopile is an instrument used to indicate very slight changes in temperature, and is constructed to utilize the electric current and the galvanometer. We will not go into its construction, but will state that this is the instrument used to record the changes of temperature in muscle when it contracts. Often an ordinary thermometer will show a marked alteration of two or three degrees upon violent use of a muscle.

Chemical changes continually occur in muscles, thus producing a certain degree of heat at all times. A certain degree of contraction always exists, as shown in the normal tonicity of the living muscle. The chemical changes, while at all times present, are increased during contraction and it is found that this change largely includes the increased consumption of oxygen and the increased expulsion of carbonic acid and sarcolactic acid. It will be noted that these acids are the products of oxidation. This increase in the acids, due to the oxidation, after a certain period changes the reaction of muscle from the normal alkaline to acid.

While it is true that the katabolistic process is being carried on and the by-products of oxidation are being thrown off at all times, when an excised muscle is made to function by the application of electrical stimuli, the anabolistic process is also being continued by the uniting of oxygen with other substances that may form living protoplasm. In the case of excised muscle where the supply of oxygen is not of the proper proportion, the anabolistic materials soon become deficient, and products of katabolism begin to accumulate in the muscle substance. This gives rise to fatigue, acid reaction of tissue, coagulation of the proteins and finally inactivity. During contraction there is also an increased consumption of carbon from the carbohydrates which are stored in the muscle tissue, and the glycogen is changed into sugar. There seems to be practically no increase in the consumption of nitrogen during contraction.

Fatigue is the result of a continuous stimulation upon the muscle nerve preparation and is indicated by the contraction of

the muscle becoming weaker and weaker, longer and longer, until finally there is no alteration in the muscle whatever when the stimulus is applied. The question now which comes to mind is, whether the fatigue is a condition of the muscle itself, of the nerve, or of the end plate. If a stimulus is applied to the muscle preparation, instead of to the nerve leading to it, the contraction takes place with very little indication of fatigue, showing that if fatigue does exist here, it is of a negligible degree. Now, if a stimulus is applied to the nerve just at the junction with the end plate, it refuses to respond, thus determining that the fatigued condition is in the end plate itself.

Fatigue is that condition wherein the functional activity of a part is lessened because of the continued use of it and is produced partly because of the consumption of the anabolistic products, and partly by the accumulation of by-products in the substance of the organ. Lactic acid is one of the principles which produces fatigue, and if it is circulated through a muscle preparation it produces all the symptoms of fatigue, while if oxygenated blood is forced through after it, the ill effects rapidly disappear and soon the muscle is normally excitable. In the living individual, however, one would suppose that the serum circulating through the tissues at all times would serve to maintain the proper nutritive materials and to carry away the waste products. This it does, but if the activity of the body is so marked that more by-products are manufactured than can be carried away, then the symptoms of fatigue make their appearance. Or, if the serum receives from the tissue more waste materials than can be eliminated during activity, then it retains the sarcolactic acid, carbonic acid, etc., and thus an effect is produced upon the entire system. This effect is upon the central nervous system, which seems to be much more susceptible to the action of the by-products than the end plates of the muscle. If, for instance, the index finger of the right hand is made to contract a great number of times to lift a weight, the period finally comes when the muscles of the finger cannot con-

tract to perform their work. Now, however, if the nerve supplying the finger is stimulated, it will contract strongly. There can be only one conclusion drawn and that is that the nerve cell of the brain is very sensitive and much more susceptible to the influence of the by-products than the muscle fibers or the end plates. Undoubtedly there is some physiological change which goes on in the brain cell during its activity, else every nerve cell would be affected alike and the result would be a complete bodily exhaustion instead of a local fatigue of a single part.

Experimentation has also led us to the important conclusion that a nerve fiber cannot become fatigued to the extent that reparation may not be made between each impulse. It was long a matter of discussion whether or not the medullary sheath did not repair the nerve axon, but this is not true, because the non-medullated nerves are no more susceptible to deterioration upon use than are the medullated. Then, too, there has been offered the suggestion that perhaps the nerve does not undergo katabolistic change upon the passage of impulses over it, but this idea has not met with approval, first, because it is not reasonable that nerve tissue of all tissues found in the body is the only one which may function without being subject to any change whatsoever. Secondly, it has been found that there is a histological difference in the nerve cell and in the fiber after continued stimulation, although it must be admitted that this change is very slight. At best we must find it extremely difficult to realize how impulses may be given at one hundred per second, and between the passage of the impulses the nerve has time to be repaired. This, however, seems to be true and it is only when the impulses are given at a rate of more than one hundred and fifty a second that the reparatory function seems to be incapable of coping with the increased activity.

CHEMICAL COMPOSITION OF MUSCLE

Water	76.00 per cent
True proteins	17.60 per cent

Collagen substance	3.10 per cent
Fat	1.60 per cent
Inorganic salts	1.30 per cent
Extractives	.04 per cent

Rigor mortis is a name applied to the state of dead muscle wherein there is a rigidity of this tissue due to coagulation. The chemical composition of muscle is here given for the purpose of showing the large percentage of water found in it that we may more fully appreciate the condition which exists in rigor mortis. After death ensues a condition of rigidity of the muscle begins sometimes only a few moments and sometimes several hours afterward. This rigidity usually occurs first in the muscles of the jaw and neck, and later in the upper extremities, then in the trunk and finally in the lower extremities. It is a peculiar fact that the existence of paralysis before death does not affect the approach of rigor mortis, and that those parts of the body which have been affected with it undergo the same rigidity as found in other parts. This leads us to the conclusion that there is nothing lacking in the cell, nor is there anything present in the cell which would call for the inactivity, and the only possible solution is in the brain system. Why the brain system? Because the mental impulse which travels from the brain to the muscle cell causes contraction, and when it cannot be properly transmitted the muscle cannot act. The ability of the muscle to undergo rigor mortis proves that the cause is not in the composition of the muscle, but must depend upon some outside influence. Is it the blood? Is it the lymph? Is it the serum? Or, is it the mental impulse? If it were blood, serum or lymph, the nutrition of the muscle would be so affected that the contraction of rigor mortis could not exist.

This fact, that rigor mortis occurs after death even in those tissues where paralysis existed during life, is one of the many clinching arguments which proves that the paralysis is caused by a lack of the supply of mental impulses through the nervous system. There is only one point in the nerves passing to the muscles of

the extremities where any impingement is likely to occur, and that is where they emerge from the bony cavity in which the brain and spinal cord are enclosed.

To follow in detail the process which takes place in rigor mortis, we must know that a coagulation takes place in the reticular substance of the muscle fiber. This coagulation is very similar to the coagulation of blood after death, and is produced by myosin (similar to fibrin in blood) forming a dense network and squeezing out the liquid substance of the reticulum. After the condition of rigor mortis has been present for some little time the muscles begin to relax, and again become pliable and flaccid. This for a long time was supposed to be the result of putrefaction, but in many cases it is found to occur long before the stage of putrefaction could intervene. The solution is then that after death ensues, when the controlling mental impulses are cut off, the muscle fiber has nothing to guide it. It is then an independent organism, not a part of the body with the exception that it is connected with other cells by a cementing material. It is independent in that from the time of death it is not governed by an intelligent force, through the brain system of the individual, and so does not function in harmony with any other cell in the body. It is at this time that matter becomes wholly subject to the laws of chemistry and physics, because the vital force of the house has been withdrawn. It is the chemical change which now causes the muscle cell to relax. A pepsin like ferment is present in the muscle, and after rigor mortis sets in the reaction of the muscle becomes acid. The ferment acts best in an acid substance, and therefore, immediately begins a self-digesting process in the cell. This of necessity tends to soften the muscle fiber and produce the relaxation heretofore mentioned.

Plain muscle has not been so thoroughly studied as to its action in rigor mortis, but the composition of it is very much the same as the striated, and it is thought its reticulum coagulates just the same as in the latter type. Voluntary muscle has been

so named because it is directly under the control of the educated volition and "involuntary" has been so named because it is not under the control of the educated will.

The same kinds of stimuli may be used in the experiments with non-striated muscle fibers as in the striated type, but while tetanus may be shown in the latter, it cannot be demonstrated in the former. In the non-striated type, the stimuli, instead of being superimposed one upon the other as in the striated type, are disregarded, and each contraction, instead of being a prolonged shortening, is a slow, simple muscle contraction. If other stimuli are given while the primary stimulus is still producing action, they are thrown off without any effect whatsoever.

Rhythmicality is a characteristic feature of plain muscle and is merely the alternate contraction and relaxation at certain definite intervals. This is illustrated in the case of the heart, the intestine, the bladder, etc.

Rhythmicality must be distinguished from peristalsis. The latter is an alternate contraction and relaxation, but progresses along the course of the muscle from one end to the other. It begins as a wave of relaxation of the muscle fibers (in the intestines just ahead of the bolus of food) and following this there is a wave of contraction of the circular fibers, forming an area wherein the lumen of the tube is decreased. Let us consider how this action is produced.

Practically every plain muscle is controlled in its movements by Innate through two sets of nerves: One (accelerator) increases the action and the other (inhibitor) decreases it. Taking the intestine as an example we will assume that a quantity of food has passed from the stomach into the duodenum. This bolus produces vibrations, and a call is sent over the afferent nerve to the brain, where an interpretation is made. The Innate Intelligence resident here immediately sends out impulses, not only of acceleration but also inhibition, and as a result the intestine ahead of the food bolus relaxes, while that behind it contracts.

CHAPTER XII

NERVE

The brain system is divided into two great divisions, so named from their location and functional activity. They are the central and peripheral systems. The central brain system is that division which is contained within the cranial cavity and the spinal column, and is composed of the brain and spinal cord. The peripheral brain system, is composed of those nerves which connect the central system to the rest of the body, and carry impulses from the tissue cells to the central cells of the brain or cord and vice versa. Those nerves which convey impulses from the brain to the tissue of the body are called efferent nerves, as is well illustrated in the case of the movements of the body. First, there is an interpretation in the brain as a result of which an impulse starts to each muscle fiber of a muscular organ; this causes the muscle to contract and movement is the result. Those nerves which convey impulses to the brain from the tissue cell are called afferent nerves and may well be illustrated in the case of the sensation of heat. The heat vibrations occur at the terminal extremity of a nerve fiber, and thus starts an impulse from the periphery to the brain, where it is interpreted as a sensation of heat. While the above illustrates the distinction between afferent and efferent nerves, it will be seen that this distinction is merely a physiological one and has to do only with function. There is no discernable distinction in the histology of the two types.

In the examination of the central brain system we find that it is composed of two substances. One of them is gray in color and one is white. Upon examination with the microscope we learn

that the gray tissue is that area which is composed principally of nerve cells, while the white is that division wherein nerve fibers are widely distributed. In the brain the gray substance is found principally on the surface, while in the cord this condition is reversed, the white being on the external, and the gray on the internal.

Upon making a cross section of a nerve it is found that the entire structure is surrounded by a fibrous sheath known as the epineurium and this fibrous tissue not only forms an ensheathing membrane for the nerve, but extends in, surrounding and holding in situ the funiculi. A nerve is made up of many fibers, but these fibers are arranged in groups known as funiculi, which are separated from one another and bound into one common mass by the enveloping epineurium. Surrounding each funiculus there is an additional membrane which is called the perineurium. Each fiber in the funiculus is joined to every other fiber by a cementing material known as endoneurium, thus forming of each funiculus a miniature nerve trunk.

The nerve fiber is the unit structure of the nerve and is merely a prolongation of a nerve cell. It is, in fact, a long branch of the nerve cell, which in company with many other branches, may find its way to any part of the body. From a histological standpoint nerves may be divided into two classes, the medullated and non-medullated. The medullated exist in the white substance of the brain and spinal cord, the non-medullated in certain parts of the peripheral system.

The medullated fibers are those which have deposited around the central core, a white, fatty substance, known as the white substance of Schwann or the medullary sheath. Outside this, binding it around the central core, or axis cylinder, we have an enveloping membrane which is known as the primitive sheath or neurilemma. The axis cylinder, which forms the center of the nerve is the true projection of the nerve cell and is the essential element over which the impulse is carried.

The axis cylinder is made up of a number of very fine fibrils and the surrounding white substance is formed of a framework in the meshes of which are held the small globules of fat, giving to it the characteristic white color. This framework which supports the fat is made up of a substance known as keratin, which is hard and horny in its consistency and offers a sturdy framework for the softer parts. At intervals in the course of the nerve fiber, the white substance of Schwann is absent and here the surrounding neurilemma is in apposition with the axis cylinder itself. These spaces between the stretches of white substance are filled with cementing material, causing the nerve fiber to bulge out at these intervals, hence the enlargements known as the nodes of Ranvier. That part of the nerve fiber which is between the nodes and contains the white substance of Schwann is known as the internode. Upon staining the fiber with silver nitrate the substance forming the node of Ranvier assumes a dark color as does part of the axis cylinder, thus presenting a small cross-like appearance, which is called the cross of Ranvier.

Nerve fibers vary greatly in size. The largest fibers are about 18 micromillimeters in diameter and the smallest about 2 micromillimeters. The nerve trunks also vary much, the greatest in diameter being the sciatic nerve, which measures about three-fourths of an inch. From this size there is a decrease until small trunks of microscopic size are reached.

The non-medullated fibers are those which have no white substance of Schwann surrounding the axis cylinder; rather the neurilemma comes in direct contact with the axis cylinder. The non-medullated fibers are sometimes called the fibers of Remak.

Nerves terminate in striated muscle by a special ending, which is known as the end plate. As the nerve fiber approaches its point of termination it divides into several branches (these branches, in the case of medullated fibers, occurring at the nodes) which pass to individual muscle fibers, and here the neurilemma of the nerve and the sarcolemma of the muscle become con-

tinuous; also the white substance of Schwann abruptly ends as the nerve fiber enters the muscle fiber. After piercing the sarcolemma the nerve terminates by a mass of nucleated protoplasm in the substance of the muscle fiber.

The nerves which supply the plain muscle fibers are usually of the non-medullated variety with the axon surrounded only by the neurilemma. Instead of the fiber branching and entering the muscle fiber directly, a plexus is usually formed about the muscle to be supplied and, from the points of intersection of the nerve fibers small terminal branches are given off, which proceed to the muscle fiber and terminate in the sarcolemma.

Nerves originate during the course of development as prolongations of nerve cells. The nerve cell in developing gives off several branches which wind around surrounding cells and tend to hold the units into a common mass. One branch, however, is a prolongation which has the ability to transmit mental impulses, and it is known as the axon or axis cylinder. The axis cylinder is then merely a prolongation of the nerve cell, which uniting with many other nerve cell prolongations, forms a nerve trunk. At the point of its origin from the central cell, the axon has no primitive sheath (neurilemma) nor medullary sheath (white substance of Schwann), but as soon as it enters the white substance of the cord or brain it takes on medullary covering, and when it leaves the cord or brain, it assumes a neurilemma. The medullary sheath is derived from the outer layer of the axon, and thus is of epiblastic origin. The neurilemma is derived from mesoblastic cells which surround the axon.

SECTION III

BLOOD

CHAPTER XIII

COMPOSITION OF BLOOD

In consideration of blood as one of the connective tissues we have to overcome the idea that the blood is a fluid and not a tissue. It is only natural that one should think of the blood as a fluid, because it is constantly changing the relation of its molecules with one another and it is further passing from one part of the body to another so rapidly that to consider it as one of the connective tissues, together with bone and cartilage, seems incorrect. However, it must be remembered that blood is a substance which contains a large proportion of serum and that this serum acts as a carrier for the more solid parts, conveying them to different parts of the body together with the nutritive materials in the serum. It is essential that they should be thus conveyed because the blood corpuscles, which form the greatest bulk of the solid material must reach all tissues of the body to perform their peculiar functions. The fact that in blood we find connective tissue corpuscles and intercellular materials, serves to classify it with other connective tissues.

Every living organism must continually be built up, for at all times the materials which they possess are being destroyed and used. The different organs are doing their utmost to break up into the simplest possible units the compound substances, and these simple units are being used to build up the worn out parts. This activity of the organs in breaking up the compounds for use

in the body is directly under the control of Innate Intelligence, because there must be some central medium whereby all organs function in harmony and the action of one is in complete coördination with that of every other one. In the very simple unicellular animals these changes take place at the surface of the cell. It is here that materials are taken in which build up the destroyed protoplasm, and it is here also that the waste materials, and those which are no longer necessary in the metabolism are given off. In the more complex organisms, however, there are millions of cells, each one of which must be supplied, as in the unicellular amoeba, with the materials with which to carry on anabolism, and must have a means of expelling the products of katabolism to the external. In man this is accomplished by the serous system, of which the blood is a part, because it is made of such a large percentage of serum. It is the function then of the serum in the blood to convey nutritive materials to all parts of the body and to convey waste materials from the point of manufacture to a place where they may be successfully expelled from the body.

STRUCTURE OF BLOOD

Blood is a connective tissue circulating through the tissues of the body, which is made up of a liquid serum, known here as the plasma, and the blood corpuscles of the white and red varieties. When the web of a frog is placed under the microscope, it is noted that passing through the small capillaries are many cells, of a yellowish color, which in passing through the small vessels, change their shapes to accommodate themselves to the size and shape of the lumen, and that they sometimes flow singly and sometimes several abreast, dependent upon the size of the vessel. These corpuscles are carried along in the stream of a colorless fluid, which is the blood serum, and these cells which are so much in prominence are the red blood cells, or erythrocytes. Clinging to the wall of the capillary and being carried along more slowly than are the red cells, are comparatively few, large, colorless, oval cells, which are known as the white blood corpuscles, or leucocytes.

ERYTHROCYTES

In different specie of animals, the red blood corpuscles differ, not only in size, but in shape. In some they are eliptical, but in man they are disc shaped, biconcave cells, about 8 micromillimeters in diameter. There is a stroma found in their structure which acts as the framework of the cell, and this being made of elastic material, accounts for the great change which may be made in the shape of the cell in passing through the capillaries, without any permanent ill effect, as the corpuscle immediately regains its normal contour upon being released from its cramped quarters. This elastic network is more dense at the outer border of the cell than on the inside, and seems in this region to form a dense network which almost forms a capsule, although with interspaces between the fibers. The haemoglobin is the most important substance found in the red blood corpuscle, and is in reality the pigment which gives to it the characteristic yellow-red color. It is not held in solution as haemoglobin, but if in solution at all, is in combination with some other complex substance. It is the generally accepted opinion that it is a semi-solid substance attached to the elastic stroma of the red corpuscle and filling the interspaces between them. The rouleaux formation of the red blood corpuscles upon a specimen of shed blood being spread upon a glass slide, is so designated because of the tendency of the cells to adhere to one another, with their biconcave surfaces in apposition, and the row thus formed suggests a pile of coins, one placed upon the other. No satisfactory explanation of this peculiar arrangement has yet been made. In all mammals, including man, the blood corpuscles are similar in shape, and not widely different in size, but in none is there a nucleus. In amphibians the cells may be oval in shape, are usually larger than those found in man, and possess nuclei.

LEUCOCYTES

The white blood corpuscles are unlike the red corpuscles in that while the latter are peculiar to blood, the former, many of

them are found in various other tissues. These white cells have the power of thrusting out from their bodies projections of their protoplasm, then withdrawing the projecting, and thus they are possessed of a means of locomotion, because the extended projection finds lodgement upon some other cell, and pulls its entire body in that direction when it is withdrawn. This action is known as amoebic movement, being a peculiar action first noted in the amoeba. It is by this means that the white corpuscles are able to find their way from the blood stream out into the surrounding tissues, move about in them and after a time to return again to the blood stream. Thus the white blood corpuscles do not remain entirely confined within the vascular walls, but move about and are part of other tissues.

The leucocytes, however, are unlike the red blood cells in that they do not possess the same size, the same degree of granulation, nor do they possess the size and shaped nuclei. Dependent upon these differences, they have been designated under different subheads, some investigators differing in this subdivision from others but all agreeing in the main.

Lymphocytes. These are types of colorless corpuscles which are relatively small, being about the same size as the red corpuscles (8 micromillimeters). The nucleus is comparatively large and is surrounded by a small border of protoplasm. It is oval in shape and located in the center of the cell. The protoplasm is not granular and stains, as does the nucleus, with basic dyes. About 24 per cent of the total white blood corpuscles are lymphocytes.

Large Mononuclear Leucocytes. This type of corpuscle is so named because it is possessed of a single nucleus, and because of its comparatively large size. It is about 16 micromillimeters in diameter and has a nucleus which is comparatively small. The protoplasm which surrounds the nucleus is not granular and it, together with the nucleus, stains with basic dyes. This type forms about 1 per cent of the total white blood corpuscles.

Transitional Leucocytes. This type is so named because it is thought by many to be in a state of change from that of the large mononuclear cell to the polynuclear cell. This fact is disputed by some but the fact remains that the nucleus of this type while not separated, has one or more constrictions, which make it lobular in appearance. The protoplasm is slightly granular and is stained by basic dyes as is the nucleus. It is slightly smaller than the large mononuclear leucocyte, and constitutes between 2 and 3 per cent of the total corpuscles.

Polynuclear Leucocytes. This type of leucocyte is found forming about 70 per cent of the total number of white cells, and is so named from the fact that there are several nuclei held in its protoplasm. About 10 micromillimeters in diameter this cell contains fine granules, and its protoplasm stains best with neutral dyes, while the nucleus, like the nuclei óf other leucocytes, takes the basic dye.

Acidophile Leucocyte. In this type we find that its name is applied because of the intense affinity which the large granules of its protoplasm have for acid dyes, such as eosinophile when treated after being taken from the body. Its nucleus, or nuclei, if there are more than one, are irregular in shape, and stain with basic dyes. These leucocytes comprise about 2 to 3 per cent of the total number of white corpuscles and are about 13 micromillimeters in diameter.

Basophile Leucocyte. These leucocytes are usually considered with the blood corpuscles, but in reality are not typical, as they are found in comparatively small quantities in the blood, while in some of the other connective tissues they are more widely distributed. They have an irregular shaped nucleus, and the protoplasm contains granules. Unlike the granules of the acidophile leucocytes, however, these granules stain deeper with basic dyes than does the nucleus itself, and for this reason the cells are known as the basophile leucocytes. They are about 10 micromillimeters in diameter and comprise about 0.5 per cent

of the total number of leucocytes. The basophile leucocytes are known in the tissues as the "mast cells of Erlick," and in fact bear that name also when found in the blood.

Blood Plates. These small bodies are irregular in shape although usually either round or oval. They are only about 2 to 3 micromillimeters in diameter, and show distinct amoebic movement. It is not known whether the blood plates have nuclei or not, and much discussion has been held in regard to their origin. The fact that they have been seen in the capillaries points to the fact that they are not derived from the disintegration of other substances of the blood, and must, therefore, be formed by some tissue of the body. It is probable that they are derived from the centers in the bone marrow. These blood plates seem to be important in the coagulation of blood, and it is noted that in specimens taken from the individual they break up and it is then that coagulation takes place. If a chemical is introduced which prevents their breaking up, coagulation does not occur.

CHAPTER XIV

COUNTING THE BLOOD CORPUSCLES

The counting of the red or white corpuscles is done by the use of the haemacytometer, which enables the investigator to mix a certain amount of blood with a liquid, which will not destroy the corpuscles, diluting it to a known degree in this manner, and by the use of the microscope counting the number of corpuscles in a given part of this diluted fluid.

The results obtained show the red blood corpuscles to be far in excess of the white. The former average about 5,000,000 to the cubic millimeter, while the latter show about 10,000 to the cubic millimeter. These figures, however, show only the mean averages and the number of both the red and white may be greater or less and still be normal to the individual. In certain diseased conditions the number of white or red blood corpuscles is markedly increased or diminished. In some cases of anaemia, which is a disease characterized by a lack of red blood corpuscles, the number is found to be as low as 1,000,000, and in rare cases even lower than that.

In case of disease of the heart, wherein the foramen ovale is not properly closed at birth, the blood is not properly oxygenated and as a result the corpuscles, under the direction of Innate Intelligence, are increased that a greater amount of oxygen may be carried in a given volume of blood. This feature, which allows for the deficiency of oxygen is the productive factor in the existence of the cyanosis occurring in this condition. In lucaemia the count of the white blood corpuscles is greatly increased, and while the average is about 10,000 to the cubic millimeter, the count in this disease shows it to be often as high as 250,000, or even more.

At the same time there is an enormous decrease in the number of red blood corpuscles, and when the disease approaches a fatal termination the ratio instead of being 1:500 may be as low as 1:10.

It must be understood that while the decrease or increase of the red or white blood corpuscles in various diseased conditions is directly productive of the various symptoms such as cyanosis, etc., that the primary cause of this deficiency or excess is an impingement on nerves which is produced by a subluxation and that the manifestation of this impingement is in the tissue centers which are utilized by Innate Intelligence in their formation.

Besides the changes which occur as the result of pathological conditions, certain changes occur physiologically in the normal individual. Immediately after a meal the number of white blood corpuscles is markedly increased, especially if the meal has contained large quantities of fat.

Bearing in mind that the white blood corpuscles are unicellular organisms possessed of amoebic movements, and bearing in mind that this power is utilized to propel them, not only in the blood, but also in the surrounding tissues, where they are prone to wander, we may readily see how the number present in the blood may be altered by their finding residence in the other connective tissues, or how they may be increased by finding their way back to the blood stream.

To assume, however, that each white blood corpuscle is an individual cell which has the power of guiding its own activity is to put the body on the basis of an unbridled force turned loose with no controlling element and nothing to guide the application of its energy. This is never the case in the human body. Here the activity of the white blood corpuscles is controlled by by the Innate Intelligence, which is aware of the necessity of white or red blood corpuscles in every tissue, and each is distributed to that part where it is of the greatest value.

CHAPTER XV

BIRTH AND DEATH OF CORPUSCLES

Erythrocytes are red blood corpuscles which during embryonic life are developed from nucleated cells which act as the centers for the secondary erythrocytes, and the latter pass into the blood stream. The cells from which these corpuscles are so derived are in the blood vessel walls, and, in fact, are the central cells from which prolongations are sent out forming the small capillary network. The red blood corpuscles in the embryo are nucleated, and in this respect are entirely distinct from those which occur in adult life. In later life the red blood corpuscles are manufactured principally in those locations where red marrow is located, as between the tables of the scull bones, in the red marrow of the bones of the trunk and extremities. Here we find developed in their own framework, haemoglobin, which gives to them their peculiar color. Soon after their production they lose their nuclei and thus approach the type of cell which is known as the erythrocyte. According to their size these developing cells which are found in the marrow are called normoblasts, megaloblasts and microblasts. The normoblasts are about the size of the fully developed erythrocyte, and the other two types are thought to be abnormal cells, present only when the subject has a diathesis toward or is suffering from certain diseases. The normoblasts are thought to mature into the fully developed red blood corpuscles. To some of the other organs is ascribed the function of manufacturing red blood corpuscles, but the conclusions reached in investigations tending to prove this point, have been insufficient to establish it absolutely.

The regulation of the amount of blood is controlled very

nicely by Innate Intelligence through the nerve fibers, which supply the organs of production, and by the mechanical features governing the pressure of the blood in the vascular system. If a hemorrhage takes place and a great amount of blood is lost, the pressure of the blood in the vascular system is decreased and thus less resistance is offered to the lymph which enters the venous system by means of the right lymphatic duct and the thoracic duct. Also less pressure is offered in the capillary system, and less serum leaves the blood. More fluid is absorbed in the intestines from the foods and less fluid is expelled through the urinary system and the skin. This increase in the amount of fluid taken into the vascular system and the decrease of the amount taken away tends to replenish the supply in the blood vessels, although it must be admitted that for a time the fluidity of the surrounding tissues is decreased.

One naturally asks the question why all this change takes place; why greater amounts of fluid are taken in and less amounts expelled. Here we have again an instance where the activity cannot be explained by the mechanical or chemical laws which control dead matter. In each body there is an intelligence which, through its nervous system, controls the activity of every cell in the body, and when this Innate Intelligence becomes aware of the decrease in the amount of blood in the vascular system, due to hemorrhage, she not only sends down reparatory impulses to decrease and finally stop the hemorrhage, but she also exercises through the nervous system and the cells of the capillaries the selective influence which serves to obtain from the surrounding tissues, those materials which are necessary to produce the proper quantity and quality of blood. This she is able to do because no condition in one part of the vascular system is considered without an equal consideration of another part, and the entire activity is blended into one harmonious whole.

Not only does the fluid increase in quantity but the corpuscles are also replaced by an increased activity of Innate Intelligence

in sending impulses to those centers where the corpuscles are formed. Indicative of this unusual activity of the corpuscle forming centers is the fact that at this time the red blood corpuscles are many of them endowed with nuclei, and resemble in every respect the nucleated normoblasts. This leads to the conclusion that the normoblasts are pressed into service while still in the condition in which they are, as a rule, retained in the red marrow.

The origin of the red blood corpuscles has been considered, and we may now pass to the question of where the process of disintegration occurs and how long the corpuscles exist as an organism in the body. Evidence points to the fact that the disintegrated red blood cells are broken down and their haemoglobin used in the manufacture of the coloring matter of bile and urine. Where the red blood corpuscles are broken down has been a matter of discussion and the idea has long been held that they were broken down in the substance of the spleen. Later investigation, however, does not support this view, and it is now thought that the great majority of erythrocytes die and are disintegrated in the blood stream, from which parts of them are taken out upon reaching the liver or kidneys, where they form the coloring matter of bile and urine.

As to the life of the red blood corpuscle there have been no proofs offered whereby an accurate estimate may be made regarding the length of time elapsing between their birth and death.

Investigators seem to be agreed upon the origin of the red blood corpuscles better than upon that of the white cells. Various theories have been advanced dealing with the method of producing the white blood corpuscle, and these ideas in main may be divided into two groups. One is known as the monastic and the other as the dualistic, because one holds that all the white cells originate from one tissue, while the other holds that they originate from different tissues. The supporters of the

monastic theory maintain that the leucocytes of whatever variety they may be are developed from the lymphoid tissue, while the supporters of the dualistic theory claim that only the lymphocytes originate here, and that the other types of the leucocytes are developed in bone marrow. Recent investigation seems to support the monastic theory, although the question is by no means settled, and it cannot be stated definitely whether the one or the other will finally be proven. We do know, however, that the lymphocytes are derived from lymphatic glands of the lymphatic system, because they are found in large quantities in the lymph which is flowing through the lymphatic ducts toward the vascular system, and because the lymph entering the lymphatic nodes does not contain nearly so large a percentage of lymphocytes as does that leaving the node. Nor is the manufacture of lymphocytes confined alone to the lymphatic glands, because these small corpuscles are found to some degree in the lymph which has not as yet passed through any of the nodes. The presence of a few of these may be accounted for by the fact that they find their way out from the vascular capillaries, and thus into the lymphatic stream, but it is also noted that lymph passing through isolated masses of lymphoid tissue, such as the tonsils, solitary glands, Peyer's patches, etc., becomes burdened with numbers of white lymphocytes.

The white blood corpuscles are not only difficult to investigate, in regard to their origin because of several different types of them, but the fact that they contain no distinctive substance as do the red, makes the study of their ultimate end a matter largely of conjecture. Several interesting and helpful features are known about them, and from these points certain conclusions may be drawn. It is known that the white blood corpuscles find their way by diapedesis to the region without the capillary walls, and by their peculiar activity travel through the various tissues in which they may find themselves lodged. In brief they are not corpuscles peculiar only to the blood, but intermingle with

other cells outside the vascular system entirely and in every part of the body.

Because every action of a living body is controlled and governed by the Innate Intelligence resident within that body, we cannot conclude that the actions of the white blood corpuscles in passing through the tissues is without a purpose. Every time a leucocyte makes its exit from the vascular system it is under the direct control of Innate, which is aware of the action of every other corpuscle at the same time and controls all in their activities. In brief, the emission from the vascular system and the return to the vascular system is not a matter of happenstance, but is due to a need which the corpuscle is not individually aware of, but which the Innate Intelligence realizes through the medium of impressions received through the nervous system.

It is further known that Innate offers the white blood corpuscles as a resisting army against the invasion of the body by any foreign material, and, in fact, does everything, even to the giving of the lives of these small bodies, in the effort to rid the system of foreign invaders if such should make their appearance. Sometimes the white blood corpuscles are unable to destroy the material and many of them lose their lives in the attempt, but their places are taken by others and the business of battle goes on till one or the other is conquered. In practically all fevers the spleen is enlarged by Innate as an adaptative feature in manufacturing an extra amount of white blood corpuscles in order to combat the poisons which are always present in the body during fevers.

If a sliver is stuck into the finger and left there, Innate immediately surrounds it with white blood corpuscles which do their best to destroy it. Those which lose their lives are deposited about the sliver, providing they die in such great numbers that they cannot be carried away by the serous circulation, and thus we have formed the white fester which is Innate's method of surrounding the foreign matter with a covering to protect the surrounding tissues. This is one way in which the white corpus-

cles are destroyed, and it may be well to assume that many of them die in the blood stream in combating the various substances which are detrimental to the body, and their remains are passed out through the serous system.

Reaction of the Blood. The reaction of a substance depends upon the comparative quantities of hydrogen ions and of hydroxial radicle ions. If the former are in excess the reaction is acid, and if the latter are in excess the reaction is alkaline. It is found in the blood that the reaction is slightly alkaline although the degree of alkalinity is very slight, and for that reason blood is often spoken of as a neutral fluid. There is a peculiarity about the blood and that is that the reaction is very constant not only under normal conditions but in pathological conditions. Even in diabetes the reaction is still alkaline, when it is known that great quantities of acid are being manufactured. The physiological factors which are concerned by the acidity or the alkalinity of the foods taken, have very little effect upon the reaction of the blood, and we begin to look for a reason for this peculiar circumstance. It is found largely in the fact that the proteins of the blood may act either as acids or bases, and when either an acid or base is added to the blood the proteins act as the opposite and neutralize the effect.

Viscosity. The viscosity of the blood is several times greater than that of water, and in passing the blood through a small tube from a vessel it is found that the rapidity with which it flows depends upon the viscosity, and the slower it flows the greater the viscosity. Sweating takes from the blood some of the water contained, and as a result the blood becomes more viscid. Any fluid when it becomes heated is less viscid than when at a lower temperature. This factor then has the same bearing in man as upon fluids outside the body, and it is found that the greater the temperature the less the viscosity of the blood. In cases where the numbers of either red or white blood corpuscles is increased the viscosity of the blood is greater because the proportion of

water in the blood must of necessity be less. On the other hand, the viscosity of blood in cases of anaemia, where the corpuscles are decreased in number, is less because the proportion of water in the blood must be greater. These changes in the viscosity of the blood, however, do not affect the blood pressure to any great extent because of the Innate regulation of the circular fibers of the arterioles.

Innate Intelligence, ever performing its function of acting as a controlling agent in the body, becomes aware of the increase of viscosity in the blood through the impressions received over the afferent fibers of the nervous system. In order that this increased viscosity may not effect the rapidity with which the blood should be distributed to the tissues of the body, impulses are sent down to the circular fibers of the arterioles which cause them to relax; the resistance to the blood is thus decreased and the supply continues in the proper quantity. If, on the other hand, Innate becames aware of a decrease in the viscosity of the blood, impulses are sent down to the circular fibers and they are caused to contract that the more fluid blood may not pass too rapidly into the capillary and venous system and produce an engorgement here.

Specific Gravity.—The specific gravity of blood varies as does the viscosity, although not possibly in the same degree. Thus in anaemia when the viscosity of the blood is less than the normal the specific gravity may only be 1.035, while under normal conditions it is about 1.055.

Volume of Corpuscles in Blood.—By the use of highly sensitive instruments investigators have been able to estimate the relative amounts of corpuscles and serum in blood, and their results show that the serum comprises about ⅔ of the blood volume and the corpuscles about ⅓. This ratio, of course, is subject to variations, dependent upon the number of corpuscles. (The number may vary to some degree in different individuals and still not be considered abnormal.) It also varies dependent

upon the size of the corpuscles. The size of the corpuscles depends in turn upon the degree of osmotic pressure, and this upon the fluidity of the solution. In case of blood, when water is added to the serum, its osmotic pressure is decreased and the water passes into and enlarges the corpuscles. When, on the other hand, the water is decreased in comparative degree in the serum, either by the addition of solids or the elimination of water, the osmotic pressure is increased and the corpuscle sends its water into the serum, and thus it shrinks in size.

Amount of Blood in the Human Body.—Various experiments have been performed to determine the quantity of blood contained in the human body, and in former years it was believed that the amount was much greater than it really is. Later investigations have proven that about 1/13 of the body weight is composed of blood.

CHAPTER XVI

FUNCTION OF BLOOD

To some extent we have discussed the function of blood, and the discussion thus far has involved the action of Innate in utilizing the corpuscles to neutralize the poisons and foreign materials that are introduced into the body from time to time. It is erroneous to suppose, however, that with the very complicated structure shown by the blood there is no other work which it has to perform. The red blood corpuscles, because of their peculiar affinity for oxygen, under Innate control, take up this oxygen from the air cells of the lungs and transmit it to the tissue cells, where it is used in the general metabolism of all parts of the body. This, however, only shows the activities of the two kinds of blood corpuscles, and does not deal with the plasma of the blood in which the corpuscles float.

The plasma serves as a carrier for the corpuscles, conveying them to all parts of the body where they, if the mental impulse supply is normal, are able to discharge their work in maintaining health in the tissue cell.

Coagulation of Blood.—This is the property of the blood which enables Innate to form, from part of its substance, a dense non-fluid structure upon coming in direct contact with the external air, and this in itself serves the important function of preventing undue hemorrhage upon the severing of a blood vessel. In this process of coagulation it is found that there is formed a dense network of these fibers, from a substance known as fibrin, and held in the meshes of this network are the red and white corpuscles. This fibrin gradually contracts, squeezing out the liquid part of the blood, which upon examination is found to be

merely a straw colored fluid. This is known as serum, and is at this time devoid of both blood corpuscles and fibrin. The following table serves to indicate the principal substances found in blood:

Blood is composed of serum, fibrin and corpuscles.

Plasma is formed of serum and fibrin.

Blood clot is formed of fibrin and corpuscles.

The peculiarity of fibrin, however, is the fact that it does not exist as fibrin in the blood contained in the vascular system. However, there is a substance contained in the plasma which is known as fibrinogen, which under certain conditions becomes changed to form fibrin. This is proven by the fact that if sodium chloride (13%) is added to pure blood fibrinogen is precipitated and the blood then is unable to coagulate. Undoubtedly then this substance, after undergoing certain changes, forms the fibrin, which, in turn, serves to form the network for the blood clot. Evidence points to the fact that in the liver the greatest amount of fibrinogen is formed. If the blood is caused to circulate through the body for a short time, and during this time the liver circulation is cut off, the amount of fibrinogen is markedly decreased.

Thus far it would seem that fibrinogen is a substance contained in the blood which spontaneously changes to fibrin, and thus forms a coagulum. This, however, is not all that is necessary. For instance, if the fibrinogen of blood is precipitated by the addition of sodium chloride (13%) and a solution formed from this precipitate, it will not coagulate. This leads us to the conclusion that there must be something else in the blood other than the fibrinogen which is involved in the formation of a coagulum.

If blood serum is separated from the blood and a large quantity of alcohol added, the proteins of the blood are precipitated and rendered insoluble by the action of the alcohol. A substance, known as thrombin, may now be extracted, and when

a small quantity of it is added to the solution of fibrinogen a clot is immediately formed, although the solution of fibrinogen alone is not capable of coagulating. Thus we have advanced another step and have reached the conclusion that coagulation is the result of the action of fibrinogen forming fibrin, under the control of a substance known as thrombin.

Thrombin, however, very much in the same manner as fibrin is formed by the action of fibrinogen, and fibrinogen is formed by the action of thrombin, is formed by the action of another substance. Fibrin is not present in the blood as fibrin; neither is thrombin present in the blood as thrombin, and thus clotting of blood cannot take place in blood contained in the vascular system. As fibrin is formed by the action of fibrinogen under the influence of thrombin, so thrombin is formed by thrombogen under the influence of thrombokinase.

Thrombogen is found in the blood plasma, and if it were possible for thrombokinase to act upon it in the plasma we would have formed thrombin, which, in turn, would act upon the fibrinogen, producing fibrin and a clot would be formed in the blood vessel.

Thrombokinase, however, is not present in the plasma of blood. Investigators do not agree as to what structures the greatest amount of thrombokinase is derived from, but agree that it is found in practically all tissue cells of the body, to some degree in the red blood corpuscles, to some degree in the white blood corpuscles, and largely in the blood plates. In man the thrombokinase found in the blood corpuscles does not have any great bearing in the formation of thrombin, but the blood plates rupture and discharge their thrombokinase immediately upon being brought in contact with the external air. Why this action occurs is not definitely known, but the idea has been advanced that the sudden loss of carbonic acid (CO_2) increases the alkalinity of the plate, and this causes it to break up. At any rate thrombokinase is rapidly liberated not only from the blood-

plates but also from the tissue cells through which the blood must pass in escaping from the wound, and this thrombokinase acts upon the thrombogen of the blood plasma, forming thrombin. This thrombin thus formed now acts upon the fibrinogen of the blood plasma, changing it to fibrin, and thus a dense network is formed, ensnaring the corpuscles in its meshes, and the clot is so produced.

THE BLOOD AS A SO-CALLED PROTECTION AGAINST DISEASE

This is a phase of the blood which has called forth many theories and speculations, and one upon which much discussion has been based. It is the action of the blood in offering itself as a protection against disease, which is the basis for the widespread use of serums and antitoxins that in the past few years, and to a minor degree even today, has occupied so much of the attention of research workers.

The basis of serums as antitoxins was presented by Dr. Edward Jenner, when he introduced the vaccine virus which was used in the treatment of smallpox. The vaccine virus was extracted from the serum of an animal suffering with cowpox (a disease similar in some respects to smallpox) and injected into the human, thus producing an antitoxin in the body, developed for the purpose of combating the poisons so introduced. It was believed that after the antitoxins had been formed in the blood, that the blood would retain it for several years, thus enabling it not only to destroy the toxins of cowpox, but, because of the similarity of the disease, also the toxin of smallpox.

It is known that while an animal cannot resist a certain given amount of toxin, if introduced suddenly, it can if a small amount is given, eliminate it. If the amount is increased gradually the antitoxin in the body increases also and finally a time is reached when a larger amount may be given than would have originally killed the animal, and no ill effects result from it.

Why should this condition exist? Because of the increased quantity of antitoxin which Innate is able to produce in the blood, as well as other tissues of the body, and which she uses to neutralize the action of the toxin. In brief, the formation of antitoxins naturally in the body is a physiological power of which every normal individual is possessed. The Innate Intelligence in the brain is made aware of the presence of toxins in the body and immediately sends out impulses that produce activity of those cells which form the antitoxin. Thus it is formed and the result is a neutralization of the toxin, in very much the same manner that acids are neutralized by alkalies. Not that the one is destroyed by the other, but it is neutralized that it may have no harmful effects, and is finally eliminated from the body.

The practitioner of the old school knows that toxin is introduced into the body in many of the so-called contagious diseases, and that if the patient shows the effects of this toxin by becoming ill, it is because the resistive antitoxin is not formed in the body in the proper quantity and quality. He therefore attempts to compound a serum which will as nearly as possible resemble the antitoxin which should be formed in the body. This he introduces with the hope that the toxin will be neutralized and health result. He forgets, however, that the antitoxins formed naturally in the body are formed in the workshop of an intelligence so far superior to the education of man, and are compounded in such a complicated manner, that the exact duplication of them is beyond the ken of even the greatest human mind. Therefore the antitoxins, artificially produced, do not have the desired effect, not because the principle upon which their use is founded is erroneous, but because of the limitations of the human ability.

When two individuals live under the same conditions and one contracts a so-called contagious disease, while the other does not, it is true that this is because of the resistance in the body

of one and the lack of the resistance in the body of the other to the toxin which is a condition in the course of the disease. The Chiropractor, however, does not seek to manufacture a serum which, when introduced, will take the place of the normal secretion, which should be formed by the body. Rather he seeks for the reason why one body is able to form the proper antitoxin and successfully neutralize the toxins present, while the other is unable to do so. They are living under the same conditions, the food is the same, the water is the same, the habits are the same, the air breathed is the same. Why, then, is the one susceptible while the other is not? He finds the answer upon examination of the spine. He finds when a certain region of the spine shows an abnormality in the position of the vertebrae here, that certain abnormal conditions exist. He discovers upon correction of these abnormal positions (subluxations) that the individual rapidly recovers. He has not introduced an imitation serum to take the place of that which the body has been unable to supply. Rather he has released the pressure upon nerves which upon their passage through the intervertebral foramén are impinged and cannot carry the proper impulses, and by so doing allows the full amount of vitality to pass to the organs whose function it is to manufacture antitoxins. These organs form, not a mere imitation of the true antitoxin, but the antitoxin itself, which is able to successfully neutralize the action of the toxins and health is the inevitable result.

SECTION IV

THE CIRCULATORY SYSTEM

CHAPTER XVII

THE HEART

The circulatory system consists of the heart, the great central pump which propels the blood through the various channels of its course; the arteries which convey this fluid from the heart to the different sections of the body; the arterioles carrying it from the arteries to the minute capillaries; the capillaries which are of such a thin walled structure that the nutritive materials readily emit therefrom as well as the oxygen, and supply the tissues situated in their immediate locality. The venules are vessels in the venous vascular system which correspond in structure to the arterioles of the arterial system and carry blood from the capillaries to the veins. The veins are the larger vessels of the system which convey the blood from the venules where they have their origin, and finally, after joining and rejoining one with another, enter the heart by two main trunks known as the Superior and Inferior Venae Cavae. Blood, while considered by some to be a fluid, is in reality a tissue of the body, and as such must be considered as one of the structures of the vascular system.

The heart is a hollow muscule-membranous organ, conical in shape, with the base upward and toward the right, the apex downward and toward the left, situated in the mediastinal region, below the neck, above the diaphragm and bounded on the sides by the lungs; in front by the sternum, ribs, costal cartilages and

lungs; behind by the great vessels, oesophagus and posterior thoracic wall. In relation to the surrounding structures its upper border is opposite the upper border of the second left rib, while it extends toward the inferior to the level of the sixth intercostal space.

PERICARDIUM

The pericardium is the sero-fibrous sac which completely surrounds the heart holding it in situ and protecting it in a measure from the surrounding structures. Although often described as a single sac it is in reality composed of two separate and distinct organs. The outer one is composed of fibrous tissue and as the heart, is conical in shape, but instead of the apex being placed toward the inferior and left, it extends toward the superior. This is because of the fact that its fibers extend upward for about an inch and a half to envelope the great vessels which have their origin or emission toward or from this direction. Its base is at the inferior, resting upon the diaphragm, and the central tendon of this muscle is continuous with it at this point.

There is only one great vessel which does not enter the heart and pericardium from the superior, and that is the Inferior Vena Cava. This vein enters the pericardium through the central tendon of the diaphragm and proceeds to its point of entrance into the right auricle near the auricular-ventricular septum. The other great vessels, the Pulmonary Artery, the Aorta, the Pulmonary veins (four in number) and the Superior Vena Cava all enter or leave at the superior, and they are the vessels which form the trunks at the superior around which we have extending prolongations from the fibrous pericardium. These prolongations, it will be remembered, form the apex of the pericardium at the superior.

The inner pericardium consists of two layers, an outer serous membrane, which is adherent to the substance of the fibrous sac just described, and an inner serous membrane adherent to the substance of the heart, and the great vessels at the supe-

rior for a distance of about an inch and a half, when it is reflected upon itself and becomes continuous with the outer layer. The outer membrane is known as the parietal layer and the inner as the visceral layer of the pericardium or epicardium of the heart. Between them there is a thin layer of serous fluid secreted by the serous membranes, but there are no fibers connecting the parietal and visceral layers. This serous fluid offers itself as a lubricant, so that when the heart contracts and relaxes, thus changing its size, there is no special strain of changed position placed upon any of the surrounding structures, but the one serous layer glides over the other, thus distributing the alteration to all of the surrounding parts equally.

STRUCTURE OF THE HEART

The heart is five inches in length, three and a half inches in breadth and two and a half inches in thickness, weighing in the female from eight to ten ounces, and in the male from ten to twelve ounces. Its hollow interior is divided into four cavities by means of two septal walls placed at right angles to one another. These are the right and left auricles or receivers, and the right and left ventricles, those cavities from which is propelled blood to the vessels.

The right auricle is the cavity forming the superior right and anterior portion of the heart. Slightly larger than the left, it is composed of two divisions, the right superior known as the sinus venosus, and this is the main division; the other is known as the right auricular appendage and is an auxiliary cavity behind, offering itself as an assistant reservoir for the accommodation of blood. While its wall is not smooth as is that of the sinus venosus, still it bears some resemblance to it. Its corrugations are formed by the presence of small muscular folds known as musculae pectinati, and they are valuable in that in case of necessity they will allow the wall of the appendage to stretch to a marked degree. While the right auricle has a greater capacity than the left, its wall is thinner, being only two mm. in thick-

ness. This feature is adaptative because of the fact that there is a lesser pressure to overcome in forcing the blood into the thin-walled right ventricle than is required on the left side in forcing the blood into the thick-walled left ventricle. In the septal wall between the right and left auricle there is an irregularity, with its concavity in the right auricle and its convexity in the left. This depression in the right auricle is called the fossa ovalis and is the result of the closing of the foramen ovale, an opening between the two cavities existant during foetal life. A thin serous membrane, known as the endocardium, lines the right auricle as well as every other cavity of the heart, and is continuous with the lining membrane of all the vessels entering and leaving the heart.

The openings of the right auricle are:

Superior Vena Cava.
Inferior Vena Cava.
Coronary Sinus.
Foramina of Thebesius.
Auriculoventricular.

The Superior Vena Cava, smaller than the inferior, drains the upper part of the body and enters the auricle at its upper and posterior angle. This vessel has no valve guarding its opening.

The Inferior Vena Cava drains the lower part of the body, is the largest vessel entering the right auricle, has at its orifice the rudimentary Eustacheon valve, and enters the auricle at its lowest point, near the Auriculoventricular septum.

The coronary sinus is a dilated sac, about one inch in length, in which the coronary veins terminate. It drains most of the vessels which supply the heart and enters the right auricle between the openings of the Inferior Vena Cava and the right Auriculoventricular. At its opening is found the Coronary valve or valve of Thebesius, which will be described later.

The foramina of Thebesius are situated over the entire inner surface of the right auricle, but the majority of them are merely small cul-de-sac or depressions in the inner wall. In about one-third of them, however, are true openings of minute veins which return the blood from the substance of the heart directly to the cavity of the right auricle.

The auriculoventricular opening is the means of communication between the right auricle and the right ventricle, and is found in the septum dividing these two cavities. It is in diameter about one and one-half inches, and is surrounded by a fibrous band which, because of its strength, reduces the possibility of the opening becoming of greater size. It is here that we find the tri-cuspid valve, and because of this fact the opening is often known as the tri-cuspid opening.

The right verticle is situated in the anterior and right side of the heart below the auriculoventricular septum, which divides it into the upper or basal division and the lower or apical portion. In shape it is pyramidal upon longitudinal section, but a cross sectional view shows it to be semilunar, this because of the fact that the intraventricular wall bulges into it, making a convex surface. Thinner walled than is the left ventricle, because of having less resistance to overcome in forcing the blood through the short pulmonary system, than is required by the left in forcing the blood through the systemic system, it is rough and corrugated on its inner surface, due to the presence of muscular bundles which project into its cavity. These are called columnae carneae, and may be divided into three divisions; first, those which are attached at both extremities and along the entire course of their bodies, thus forming ridges; second, those which are attached at both extremities but not along the course of their bodies, thus forming arches; third, those which are attached at one extremity and are allowed to project their other extremity into the cavity of the ventricle; these are known as musculi papillares, and their apices offer themselves as a point of attachment for the tendinous cords which support the cusps of the tri-cuspid valve.

There are usually two musculi papillares in the right ventricle, an anterior and a posterior attached to the anterior and posterior walls respectively. The function of the columnae carneae is to offer themselves as supports to strengthen the walls of the ventricles, which have the majority of the heart work to perform. The entire cavity of the right ventricle is lined with endocardium, which is continuous with the lining of the right auricle and that of the pulmonary artery.

The openings of the right ventricle are:

Auriculoventricular.

Pulmonary artery.

The auriculoventricular opening we have described in connection with the right auricle.

The Pulmonary artery drains the right ventricle and emits very close to the auriculoventricular septum, at the base of this cavity. It is about one and one-fifth inches in diameter and its orifice is surrounded by a fibrous band at the point of emission, which gives it strength, thus reducing the possibility of the opening becoming greater in size. The pulmonary artery opening is guarded by a valve known as the right semilunar valve, which prevents the blood in the artery from regurgitating into the right ventricle.

The left auricle is the cavity found in the base of the heart, posterior and to the left of the right auricle. It is smaller in size than the right, although its wall is thicker, being about 3 mm. in thickness. It, at the right, is divided into two divisions; the main cavity, cuboidal in shape, and known as the sinus arteriosus, and the auricular appendage, shaped like a dog's ear and somewhat longer and thinner than the corresponding right. The small muscular corrugations are found upon the inner surface of this appendage as in the right auricular appendage, and here they also are known as the musculi pectinati, serving the purpose of strengthening and supporting the wall. Upon the auricular septal wall there is a convexity projecting itself in the left

auricle, and this is due to the corresponding depression in the right auricle known as the fossa ovalis.

The openings of the left auricle are:

Pulmonary veins.
Auriculoventricular.

The pulmonary veins are those which drain the lungs of blood which has been sent there to be oxygenated, and is now being returned to the heart to be pumped out to the entire body. Four in number they enter the left auricular cavity from the posterior, two piercing the wall on the right posterior angle and two on the left posterior angle. Their openings, as the openings of the other great vessels entering or leaving the heart, are surrounded by a band of fibrous tissue which tends to strengthen the wall at this point. There are no valves found at their orifices.

The auriculoventricular opening is found in the auriculo-ventricular septum, is oval in shape and offers itself as a means of communication between the auricle and ventricle on the left side. Though somewhat smaller than the corresponding opening on the right side of the heart, it has practically the same structure, being surrounded by a fibrous ring which not only strengthens it but offers itself as an attachment for the cusps of the valve, which on the left side is known as the bicuspid or mitral valve.

The left ventricle is situated in the posterior left and inferior part of the heart cavity, below the auriculoventricular septum. The shape of its cavity is oval upon cross sectional view and upon a longitudinal section is found to be conical. Its walls are much thicker than those of the left and it is longer, extending nearer to the apex of the heart than the right does. The various types of columnae carneae are found here as they are in the right auricle, although possibly thicker and heavier than in that location.

The openings of the left ventricle are:

Auriculoventricular.

Aortic.

The auriculoventricular opening has been described under the left auricle.

The aorta is the great artery of the entire arterial system from which are derived directly or indirectly all the arteries and arterioles of the systemic circulation. Through this vessel all the blood which is being propelled to the tissues of the body must pass. It has its origin in the anterior wall of the left ventricle above and to the right of the auriculoventricular opening. Circular in shape, its opening is surrounded by a dense ring of connective tissue to which are attached the cusps of the valve which is placed here to prevent the blood for regurgitating into the heart after being forced into the aorta. This valve is called the left semilunar valve, corresponding to the valve of like structure place in the pulmonary artery. The diameter of the aorta at its origin is 1⅛ inch.

CHAPTER XVIII

VALVES OF THE HEART

The valves of the heart are six in number and are all arranged in such a manner that the blood can pass in only one direction, and after having passed a valve cannot return to the cavity from whence it came. They may be enumerated as:

Tricuspid valve.
Bucuspid (or mitral) valve.
Right semilunar valve.
Left semilunar valve.
Coronary valve (valve of Thebesius).
Eustacheon valve.

The tricuspid valve is situated in the right auriculoventricular opening and is so named because it has three cusps or divisions. Each of these cusps is in shape trilunar, being attached at the convex border to the connective tissue forming the border of the opening; the three cusps when forced up into position entirely occlude the opening, meeting with their apices at the center of the oval. Extending from the borders of the cusps we have thin tendinous cords which are attached at their other extremities to the apices of the anterior and posterior musculi papillares. These fine strong bundles of connective tissue are called cordae tendineae and are just long enough that when the apices of the valve cusps have come together at the center of the auriculoventricular opening they are taut and prevent the cusps everting back into the right auricle. The entire aspect of the cusp with its cordae tendineae extending to the apices of the musculi papillares in the ventricles, resembles the parachute of a balloon with the tiny wires extending from it to the basket far below.

Not only do the musculi papillares offer themselves as a point of attachment to the cordae tendineae, but they have an additional function in that when the heart contracts and brings the apex of the ventricle and the base of the musculi papillares nearer to the auricular opening, these little muscular columns contract, thus keeping their apices ever at a given distance from the valve cusps, and in this manner preventing eversion, and regurgitation.

The bicuspid valve (mitral valve) has two cusps, instead of three, as has the tricuspid, and these two are thicker and stronger than those of the opposite side. The two segements of which the valve is formed are of unequal size, the anterior one being larger and thicker. Cordae tendineae are also found extending from their apices and margins as in the tricuspid valve, but the cords here are thicker and fewer in number.

The right semilunar valve is found at the opening of the pulmonary artery and serves here to prevent the blood from regurgitating from this vessel back to the right ventricle, from whence it came. It consists of three cusps, as does the tricuspid, and is formed of connective tissue, as is the latter, but there are no cordae tendineae and the shape and attachment of the segments is entirely different. Each cusp resembles an outer pocket sewn on a garment with the attached margins toward the heart and the free border turned in the direction of the great vessel in which it is placed. These cusps are placed side by side so that each one occupies about one-third the circumference of the vessel. The blood may easily flow from the heart into the vessel without meeting with any obstruction, but as soon as the pressure here begins to force it in the opposite direction, the little pouches fill with blood and are dilated until they meet at the center of the vessel and entirely occlude the lumen. This dilation is assisted by the little pouches in the wall of the vessel, one directly behind each cusp, which are never entirely empty of blood and which help to push the cusps out after the ventricles begin

to relax. These little cavities are known as the sinuses of Valsalva, and there are three of them in the beginning of the pulmonary artery, one behind each cusp. These little pouches also serve as cavities into which the cusps of the valve may recede during the ventricular contraction, thus preventing undue friction.

The left semilunar valve is found at the beginning of the aorta and identical in structure with its fellow in the pulmonary artery. The principal difference between this valve and the right semilunar are that in the right side the cusps are thinner and weaker than on the left and the Sinuses of Valsalva are deeper and larger in the latter.

The coronary valve (valve of Thebesius) is merely a thin fold of the lining membrane of the heart, strengthened by a few connective tissue fibers, which is found at the opening of the coronary sinus in the right auricle. This fold is loosely placed so that it may be pushed aside upon the influx of blood but is forced up into position when the auricle contracts.

The eustacheon valve is a semilunar projection of the lining membrane of the heart into the cavity of the right auricle. It is placed just anterior to the inferior vena cava opening and in adult life is practically functionless, although in the foetus it is of great importance.

CHAPTER XIX

CARDIAC CYCLE

The heart contracts approximately 72 times per minute in the adult human being. From this basis each cardiac cycle consumes five-sixths of a second, but for the sake of convenience in description we will assume that this time is eight-tenths of a second. The cardiac cycle should by no means be confused with the circulation of blood in the vascular system. Noting that the alternate contraction and relaxation of the heart consumes eight-tenths of a second, we also find that all parts do not contract nor relax at the same time. The contraction of the heart is known as the cardiac systole, and the relaxation as the cardiac diastole. However, as the auricles and ventricles do not have their systole and diastole at the same time it will be necessary to describe each individual action and the length of time that is consumed by each.

The auricular diastole is the name applied to that action of the heart in which the auricles are entirely at rest. Having just completed their contraction the auricles at the beginning of the rest period are empty. Immediately, however, two streams of blood begin to pour in from the superior and inferior venae cavae. This flow is governed entirely by a difference in pressure. While the pressure in the great veins is low as compared to the arteries and capillaries, still the auricles are empty, and offer no resistance whatever to the influx of blood. Further than this the walls of the auricles are thin and are affected by the elastic lungs which lie close to them. The lungs, contained as they are in the thoracic cavity, are continually on the stretch, always tending to collapse and force the air contained in them

to the external. This tendency of the lungs to collapse causes a tension, not only on the thoracic wall but also upon the walls of the auricles. Naturally this tends to create a vacuum in the auricles, thus producing suction on the blood of the great veins. The auricular diastole occupies seven-eighths of the entire cardiac cycle, or approximately seven-tenths of a second.

The auricular systole or period of contraction of the auricles lasts just one-tenth of a second or one-eighth of the entire cardiac cycle, thus completing for the auricles the entire time of the cycle, which is eight-tenths of a second. Beginning immediately upon the termination of the auricular diastole, the muscle fibers of the auricles begin to contract, starting with those around the superior and inferior caval openings and the pulmonary veins, proceeding from here toward the auriculoventricular openings. This contraction is sudden but does not require a great deal of labor, as at this time the ventricles are empty and offer little resistance to this onward propulsion. The reason why the blood is forced into the ventricles instead of back into the veins is that when the auricles contract the blood must go somewhere and there is less resistance ahead in the empty ventricles than in the already engorged veins.

The ventricular systole occurs immediately after the auricles have concluded their systolic period, and begun their diastolic period. The contraction here is much more forcible than the systole of the auricles, because the pressure of the vascular system in its entirety must be overcome. It is because of this question of resistance that the left ventricle contracts more forcibly than the right. While the right must meet and overcome the resistance of the capillaries of the pulmonary system, the left must overcome the resistance of all the capillaries throughout the entire systemic system. The capillaries are not only more numerous in the latter case, but the vessels leading to them are much longer, hence offering more wall space to obstruct the flow. The contraction lasts three-tenths of a second

or three-eighths of the entire cycle. The beginning of this force merely raises the pressure of the blood contained in the ventricles to that in the great arteries, but as this point is reached the ventricles continue to contract and finally overbalance the latter pressure, as a consequence of which the blood flows into the arteries.

The ventricular diastole occupies the remainder of the cyclic period, which is five-tenths of a second or five-eighths of the entire time. If the ventricular systole occurs immediately after the auricular systole, the former lasting three-tenths of a second, then the first three-tenths of a second of the auricular diastole occurs while the ventricles are in a state of contraction. The entire time of the auricular diastole, however, is seven-tenths of a second, therefore the last four-tenths occur while the ventricles are also at rest. In other words, there is just half the time of the cycle when the entire heart is at rest, and during the other half either the auricles or ventricles are contracting.

The table of the cardiac cycle may be given as:

Auricular systole .1 sec. Auricular diastole .7 sec.
Ventricular systole .3 sec. Ventricular diastole .5 sec.

CHAPTER XX

VALVE ACTION IN THE HEART

The bicuspid and tricuspid valves open at that period of the cardiac cycle when the ventricular systole has terminated and the pressure in the auricles becomes great enough to force the cusps downward into the ventricles. This usually occurs before the auricular systole begins, because the ventricles during the last four-tenths of a second of the auricular diastole are empty and offer no resistance to the onward flow of blood from the auricles, which are filling with blood during this period. Immediately following the auricular systole, the ventricles begin to contract and force out the blood contained in them. At this time the auricles are empty, but when the ventricles are engorged with blood the cusps of the bicuspid and tricuspid valves are floated upward and toward a proximity in the centers of the auriculoventricular openings. Therefore, when the ventricular systole begins it completes the approximation of the cusps, and thus the lumen between the auricle and ventricle is completely occluded. The cusps of the valves are prevented from everting into the ventricles, by the presence of the cordeae tendineae, and by the contraction of the musculae papillares. This latter event prevents the point of origin of the cordae from approaching too near the openings, which might otherwise occur when the heart shortens upon contraction. The mitral and tricuspid valves then remain closed until the ventricles have ceased to contract and the pressure in the auricles again becomes of sufficient strength to cause them to open.

The right and left semilunar valves open when that point

has been reached in the ventricular systole in which the blood pressure on the cardiac side has become greater than that on the arterial side. From this time it remains open until the ventricles have completed their contraction and all the blood contained in them has been forced through into the aorta and pulmonary arteries. At this time the arterial pressure has been appreciably raised, and when the ventricles begin to relax the blood starts a rush into their cavities to relieve this pressure. It is at this time the little pocket cusps of the semilunar valves open out and meet with their apices at the center of the vessel. There is only one way now for the blood to equalize the pressure in the vascular system, and that is to flow through the long course of the arterial, capillary and venous systems to the empty auricles, and thence to the empty ventricles. This it does, but the cardiac cycles follow in such rapid series that it makes a continuous difference in pressure, so the blood is always kept in motion so long as the heart beats and the valves function properly. Upon each contraction, approximately three ounces of blood is forced from the auricle to the ventricle on one side of the heart, and from the ventricle to the great artery with which it communicates.

SOUNDS OF THE HEART

Upon the application of the stethoscope to the chest wall in various regions it is found that there are two distinct sounds heard during the cardiac cycle. The first one is a long booming sound and is known as the "first sound" of the heart. The second is short and sharp and is known as the "second sound" of the heart.

Considerable discussion has been held relative to the causative factor in the production of the first sound. Some investigators have held that it is entirely due to the closing and consequent vibrating of the cusps of the mitral and tricuspid valves. Others have held that it is due to the vibration of the heart muscle itself during the course of its contraction, and that it is unaffected by the valves. Later investigations, however,

seem to point to the fact that both these factors may have to do with its production. In the excised mammalian heart, where there is no blood or other liquid involved, and thus the valves do not act, it is found that there is existant the peculiar "first sound," thus disproving the theory that the sound is dependent upon the vibration of the valve cusps. Further than this, the sound lasts throughout practically the entire ventricular systole, and it is certain if it was due to the vibrations of the cusps they would be damped before this time elapsed, by the blood pressure in the ventricles. The theory, however, that the sound is due entirely to the heart's vibrations in contraction is not borne out by the fact that if during the contraction the valves are allowed to act there is an added quality to the tone which was not present before. There seems, then, to be no question but that the first sound is due to the vibrations of the heart muscles during contraction, together with the closing of the mitral and tricuspid valves. It is a fact that the first sound may be best heard over those areas where the sounds of the mitral and tricuspid valves are most readily detected. In the case of the tricuspid from the fourth to the sixth intercostal spaces on the right border of the sternum and in the case of the mitral at the fifth intercostal space a half an inch internal to the mammillary line on the left side.

Investigators practically all agree as to the cause of the "second sound." It occurs at the beginning of the ventricular diastole and for this reason is known as the diastolic sound. It is a short, snappy sound, occurring at the time that the cusps of the semilunar valves are forced suddenly out and prevent the influx of blood into the empty ventricles. This sudden opening and checking of the progress of blood is the cause of the second sound as is proven in experiments, showing the character and exact timing of the action and sound. The second sound may be best heard over the aortic and pulmonary areas, those positions on the thorax where the aorta and pulmonary arteries approach nearest the surface. This because the vibrations are carried along the course of the arteries. The second sound caused by the right

semilunar valve is heard best in the second intercostal space on the left border of the sternum, and any defect in the action of the valve may be best heard here. Over the second right costal cartilage on the right border of the sternum is the area where the sound of the left semilunar valve is best heard, and where defects of this valve are best studied, because the aorta is making its arch approaches nearer the surface here than at any other point.

The apex beat of the heart is the short, sharp tap that is heard immediately over the apex during the ventricular systole. The explanation of it is the fact that the aorta arches toward the right and posterior forming a semicircle before it begins its downward passage. When the ventricles contract, forcing the blood into the aorta and increasing its pressure, it tends to straighten out, just as a garden hose does when the water is turned into it. The descending aorta is given a long solid foundation against the posterior thoracic wall, so the heart itself is thrown forward against the anterior thoracic wall and the first point of it that comes in contact is the apex. The apex beat is often called the cardiac impulse, and the observation of its action offers an important field for study. The instrument which is used in making these important observations is known as the cardiograph. It is not our intention to take up the study of the instruments used in physiological experiments; suffice it to say that the cardiograph is placed upon the chest and records the movements produced by the cardiac impulse. The record sheet upon which this tracing is made is known as the cardiogram and reveals an elevation corresponding in time to the auricular systole, although this elevation is small and sometimes entirely absent in man. During the ventricular systole, however, there is a marked rise of the recording needle, which corresponds in time to the period of the first sound of the heart. This elevation is maintained for about three-tenths of a second, after which it rapidly falls, beginning its drop at the time the second sound of the heart occurs, and remaining depressed for about five-tenths of a second, when it again rises during the systolic contraction of the next cycle.

CHAPTER XXI

ENDOCARDIAC PRESSURE

Endocardiac pressure is the term used to indicate the pressure of the blood in the various cavities of the heart, but owing to the fact that the auricles and ventricles are constantly changing shape and size, this pressure must of necessity vary. This feature has opened a wide field for investigation of the changes in pressure that occur in the auricles and ventricles, and the instrument which is used in procuring this data is known as the manometer so constructed that it may record exactly the variations in pressure in any cavity of the heart. It shows the following important features:

The ventricular pressure shows four distinct degrees or periods.

(1) In this period the pressure in the ventricles is less than either in the auricles or the great arteries, and as a consequence the semilunar valves are closed and the auriculoventricular valves are open, allowing the blood to pass in from the auricles. This period may be known as the filling period and occurs during the latter part of the ventricular diastole.

(2) During this period the ventricles have begun their contraction but have not as yet produced pressure great enough to open the semilunar valves. The pressure, however, is great enough to have closed the auriculoventricular valves, and as a consequence, the ventricles at this time do not communicate with any other vascular cavity. This may be termed the period of rising pressure, and occurs during the first part of the ventricular systole.

(3) The period when the pressure in the ventricles is

greater than that in the great arteries, and as a result of this the blood is forced out, causing the arterial walls to be distended and storing up in them a certain amount of potential energy dependent upon the degree of stretch that exists in them. This is known as the period of discharge and occurs during the latter part of the ventricular systole.

(4) It is during this period that the pressure in the ventricles is again less than that in the arteries and more than that in the auricles. As a result the semilunar valves and the auriculoventricular valves are all closed. This period lasts, however, for a very short time at the beginning of the ventricular diastole, and is known as the post-sphygmic period.

The auricular pressure discloses three distinct rises or positive variations and three drops or negative variations in the auricular cycle:

(1) The first positive wave is due to a rapid rise in pressure and is dependent upon the auricular systole, which forces the blood into the ventricle. The first wave of depression follows the primary rise immediately, and is due to the suddenly diminished pressure produced by the relaxation of the muscle walls of the auricles.

(2) The second positive wave occurs following the primary depression and is due to the ventricular systole causing the cusps of the auriculoventricular valves to bulge into the auricles, thus giving less space in these cavities and increasing the pressure. Following this systolic rise the second depression occurs, which may be called the systolic fall. It is due to the ventricles rapidly discharging the blood from their cavities and the relieving of the pressure of the valves by the contracting of the musculi papillaries.

(3) The third positive wave has its rise gradually and is due to the auricles slowly filling with blood from the great veins. It lasts longer than do the other positive waves. The negative period, which immediately follows this third rise, is due to the auricles being relieved of their pressure by the opening of the

auriculoventricular valves, thus allowing the blood to be accommodated in part in the ventricles. This period completes the auricular cycle and the next period is the first positive wave produced by the auricular systole.

While thus far we have been considering the physiology of the heart we have done so merely from a mechanical point of view, noting the various changes that occur in its walls, the changes in the pressure, and the times at which these activities occur. The heart, however, is not to be considered merely as an automatic mechanical organ, but as one possessed of life, and it shall be our endeavor in the pages immediately following to show the manner in which it is caused to function as a living organ in harmony with other requirements in the body and governed as are other parts of the body by Innate Intelligence through the medium of the nervous system.

CHAPTER XXII

INNATE CONTROL OF THE HEART

Nerves are found widely distributed in the auricular septum, sinus venosus, and auriculoventricular septum, where they form a very dense plexus in which are found many ganglia, from the cells of which axones are given off which supply both the auricles and ventricles. These ganglion cells are similar to the central cells of the brain and cord and are said by some investigators to control the action of the heart. It may be accepted that the ganglion cells are the medium through which the heart is controlled by Innate Intelligence, but we also have the nerve fibers leading from the brain to the ganglion and those leading from the ganglion to the various points of distribution in the heart muscle. To state that a ganglion is concerned in the process of controlling any part of the human body in its normal function is quite correct, providing the impression is not given that the ganglia controls. These are material factors, not vital factors, and therefore cannot control. The extent of their abilities is to offer themselves as agents through which Innate Intelligence may receive impressions or send out impulses. It would be as absurd to assert that the hammer controlled the nail in forcing the latter into a piece of wood. If it were not for the intelligence in man, which was directing the hammer in its movements, these two inanimate articles might lie in one place for centuries, but the hammer would never drive the nail into the wood. Every care should be taken to separate the agent from the action in the subject of physiology. Failure to do this has for hundreds of years produced no better results than could be expected from any other study founded on a wrong basis. Physiologies today are a jumble of chaos and un-

certainties because a clear distinction has not been made between the material and the immaterial. In order to prove that this contention is true it will be our attempt to set forth in the next few pages, in as clear and concise a manner as possible, two theories which have obtained for some years in regard to the automatism, rythmicality, coördination and conduction of the heart. Together with these two theories, lengthy and complicated as they are, will be set the simple Chiropractic idea, which needs no further recommendation than the strength of its logic and the clearness of its simplicity.

The automatism of the heart is the term applied to express the ability of the heart to contract without the presence of external stimuli. Scientists are disagreed upon the question of so-called automatism, some claiming that it is a quality possessed by the muscle of the heart and some claiming that it is a quality possessed by the ganglion cells. These two premises are spoken of as the myogenic and neurogenic hypotheses, and the arguments in favor of each have neither proven one nor disproven the other.

The rythmicality of the heart is that power whereby the organ is caused to contract at certain stated intervals, irrespective of the continuous impulses supplied through the nerves leading from the central nervous system. In the biceps, for instance, if a series of stimuli is applied to a muscle preparation, there is a state of continued contraction, but not so in a preparation of the heart muscle. Here, no matter how strong the exciting force, nor how continuous, the heart will beat just so fast. The same argument exists in regard to the rythmicality of the heart as exists in regard to the automatism; namely, whether the rythmicality is due to some latent factor in the muscle tissue or whether it is due to a like factor in the ganglion cells.

Conduction is the term used to express the transmission of the contraction wave from the point of origin to all parts of the heart. The heart does not contract in all its divisions at the same time, but begins the action around the great veins which empty into the auricles and progresses from here toward the

auriculoventricular openings on each side. Here there is a slight hesitation after which the contraction continues in general, proceeding from the auriculoventricular openings toward the openings of the aorta and the pulmonary artery. Whether conduction is carried out through the muscle fibers, or whether through the nerve fibers is, as in the matters of automatism and rythmicality, a matter of dispute.

Coördination is the term used to indicate the ability of the heart to contract in all its divisions at a definite time in the cardiac cycle, and in harmony with every other part. This subject is closely allied with that of conduction, for if it could be proven that conduction depended upon the action of the nerve fibers or of the muscle fibers, that same would also have to control the coördination.

Neurogenic Hypothesis

This theory is founded upon experiments made, not upon the living individual, but upon cardiac preparations made and artificial stimulations applied in the stead of the normal mental impulses. The idea that the ganglion cells of the heart regulate it and control the metabolistic process in its tissue, is founded largely upon the experiment of placing the excised mammalian heart under certain conditions (i. e., supplied by defibrinated blood) and noting that the rythmical contractions continue sometimes for several hours. This, however, is not proof of anything except that a stimulus is reaching the muscle fibers of the heart by some means. It is true that the stimuli are more apt to travel over the nerves than in any other manner, and if this occurs they must pass through the ganglion. The automatism of the heart is thought to be dependent upon the ganglia, largely because activity is associated with the presence of nerve tissue and the fact that the distinction is not made between the material through which the immaterial acts and the immaterial itself. This idea then that the action in any organ or part of the body cannot occur if the nerve supplying that part is affected, accounts for the belief that

in the excised heart the continuing of the contraction must depend upon the presence of nerve tissue here, and the ganglia being the largest masses, they are picked on as the center from which the control is derived. The rythmicality of the heart, the conduction and coördination must follow as a natural consequence, because once having decided that the power is coming from the ganglia, it would be impossible to assume that these features were peculiar possessions of the muscle fibers themselves.

Myogenic Hypothesis

There are two arguments advanced by the supporters of the myogenic theory, as to why the neurogenic theory is illogical. One is because ganglia in other parts of the body rapidly lose their power to respond to artificial stimuli after the death of the body from which they are taken, as a unit. The other argument is based upon this fact. That between the auricles and the ventricles lies the auriculoventricular membrane of connective tissue, which is pierced by a thin strip of muscle tissue, and that if a ligature is made around this strip it will at first make the action of the ventricles slower and later if drawn tighter so as to sever the muscle it will entirely stop the action of the ventricles. Supporters of this theory also point out the fact that there is a pause between the contraction of the auricles and ventricles, and that this could not occur if the means of conduction were by the nerves because of the rapidity of transmission in this tissue.

The Chiropractic Explanation of Cardiac Control

Realizing the futility of devising means of observing the heart in its normal state in man to determine the causes of many of its remarkable features, investigators have attempted to produce conditions as near like those of the body as possible, and to found their conclusions upon the results obtained in these observations. The results have been that the heart has been removed from certain of the lower animals, taken in the fresh state and placed in a solution as nearly resembling blood as it was possible

to produce. With the heart in this solution it was observed that it relaxed and contracted with a degree of regularity, and immediately extensive conclusions were drawn, which were applied, not to the heart specimen, but to the action of the human heart in its natural state in the human body.

There are three kinds of artificial stimuli, namely, the mechanical, chemical and electrical. Remembering that the atmosphere and fluids are continually traversed by mechanical vibrations, that the atmosphere and the solution in which the heart is placed are composed of chemical elements, which by their action offer themselves as stimuli, and that continually in the atmosphere and in solutions there exists a large amount of potential electricity, we begin to realize the possibility of the trunks supplying the heart being stimulated and thus keeping the ganglion cells in a state wherein they may function. All this, however, is of no avail if the tissue of the heart is not supplied with oxygenated blood or a fluid closely resembling it. When we realize how extremely sensitive a nerve is, we can more fully realize the possibility of this stimulation coming from the outside over the nerve trunks, rather than assuming that the ganglion cells are possessed of that unknown condition, vitality.

The experiments, then, upon which the neurogenic and the myogenic hypotheses are based, can be of very little value in establishing the real reason for rythmicality, conduction and coördination in the heart of the living body. Here the chiropractic explanation is the only one which stands the ultimate test of reason.

The heart is that great central pump of the circulatory system which is valuable in propelling blood throughout the vessels of the body where the oxygen is taken from it and the carbon dioxide given to it under the directing influence of Innate Intelligence. Here, as in the other organs and systems of the body, we must not lose sight of the fact that the function must be in harmony with all other parts, and that in fact the activity of the other parts of the body determines the amount of blood which Innate

will send to them. To assume that either the ganglion cells of the heart or the muscle fibers of this important organ controlled the rythmicality, the conduction and the coördination of the heart would be to grant that the heart was regulated, not as a wheel in the delicate mechanism of the body, but as an independent unit acting without reference to the necessities of the tissues of the body. This we know is not the case, for when the body is exercising violently, the heart beats faster and the blood courses more rapidly in the arteries and veins, in order that the carbon dioxide may be more readily taken from the cells, where it is being formed, and in order that the oxygen which is being taken into the lungs more rapidly may be distributed to better advantage. One cannot conceive of this wonderful coördination of action unless he recognizes the presence of Innate and understands that she has complete control over, not one action in the body, but over every action. She it is who recognizes the necessity for more oxygen and not only does she send out more mental impulses to the heart, thus producing more rapid propulsion of blood, but also the action of the muscles of respiration is increased and more oxygen is taken into the lungs in order that the blood which is being forced out more rapidly, may be thoroughly laden with oxygen.

Here we have the keynote to the cardiac activity. Innate Intelligence sends out the impulses which produce a contraction of the heart muscle, but before doing so she receives and interprets impressions from all parts of the body, thus becoming aware of the necessity for that contraction. In the heart, as in every other part of the body, there is never an action until Innate is made aware of a call for the action and a necessity for its execution.

CHAPTER XXIII

STRUCTURE OF BLOOD VESSELS

Before considering the work that is performed by the blood vessels, let us describe them that we may be the better enabled to understand the physiology of this important system in the body.

The blood vessels are divided into the arteries, the capillaries and the veins.

The arteries are musculo-membranous tubes, so named from the fact that the ancients believed they contained air. In still more remote times it was supposed that there were contained in the arteries, animal spirits, whose home was in the ventricles of the brain. How the spirits got from the ventricles to the arteries was not known, but the function of the arteries was to offer themselves as a home for the mysterious tenant.

All the arteries of the systemic system arise from one main trunk, which is the aorta, while all the arteries of the pulmonary system arise from the pulmonary artery. The aorta and pulmonary arteries may be considered as the trunks of two large trees, which give off several main branches, these in turn giving off large limbs, and the entire structure dividing and subdividing until the very terminal twigs are reached. These terminal twigs may be called the arterioles (small arteries) and they divide still further, forming very small delicate vessels called the capillaries. These capillaries, after originating from the arterioles, terminate by joining with one another, forming small vessels about the size of the vessels from which they arose, and these vessels are known as venules. They, in turn, join and rejoin, forming larger and larger veins, until finally the very largest trunks of the venous system are formed (superior and inferior venae cavae in the

systemic system, and the pulmonary veins in the pulmonary system).

Although the aorta is the largest artery in the systemic system, and its cross sectional area is greater than any other single artery of this system, still the combined cross sectional areas of its direct branches is greater than its cross section, just as the combined cross sectional areas of their divisions are in turn greater than that of the trunk from which they originated. Thus as the arteries progress further and further from the heart, the area through which the blood is flowing becomes greater and greater. In returning to the heart the same condition exists in the reverse, and the lumen of the vessels decrease as the blood nears the heart.

Throughout the entire vascular system there is a network of vessels joining one vessel with another, and especially is this true in the smaller vessels. These means of communication are known as anastamoses, and by means of them in the small vessels there is formed a dense network which permeates practically the entire body. It is because of this fact that when a vessel is ligatured because of injury or in an operation, there need be no fear of the blood supply to a part being destroyed. A collateral circulation is established by the anastamosing vessels, and the part is so supplied. Every vessel wall, however, requires its supply of nutrition and oxygen just as any other tissue, and this supply is derived not entirely from the blood in the vessel itself, but by small vessels piercing the outer coat and terminating in the middle coat of the vessels. These small vessels are called vasa vasorum, and supply both arteries and veins.

Structure of the Arterial Wall. In large arteries there are three coats forming the wall. The external coat or tunica adventitia, the middle coat or tunica media, and the inner coat or the tunica intima.

The external coat (tunica adventitia) is composed of a layer of white and yellow connective tissue fibers interspersed with some plain muscular fibers, and the entire structure connected

with a quantity of cementing tissue. At the inner border of the tunica adventitia is a thin layer where a preponderance of elastic fibers is gathered, and this forms the external elastic membrane.

The middle layer (tunica media) of the arterial wall is essentially a muscular coat, formed of nonstriated muscle fibers, but there may always be found intermingled with them quantities of yellow and white connective tissue fibers. In fact, in some of the arteries, especially the large ones, the muscle tissue is almost entirely replaced by elastic tissue. The muscle fibers are arranged as a rule circularly, but occasionally there are bundles present, which run in a longitudinal direction.

The inner coat, or tunica intima, consists of three layers; the inner one is that which lines the lumen of the vessel and comes in direct contact with the blood. It is the endothelial layer, the cells of which are flattened and arranged one overlapping another, as the shingles on a roof, so as to offer the least possible resistance to the propulsion of the blood. Immediately next to this endothelial membrane is a thin layer of fibrous and elastic tissue, which is known as the subendothelial layer, and it offers itself as a base upon which the endothelial cells are placed. The external layer of the inner coat is known as the internal elastic layer or fenestrated membrane of Henle, and is, as the name implies, formed of yellow elastic fibers.

As the larger arteries become smaller in approaching their terminations, certain changes appear in the structure of these vessel walls. Principally the change is in the coats becoming thinner, but in the very small venules and arterioles, there is an absence of the subendothelial layer and the endothelial cells rest directly upon the internal elastic membrane.

The Structure of the Venous Wall.—The veins possess the same general features as the arteries in their structure. They have a tunica intima which is practically the same as that of the arteries, with the exception that there are more white fibers and less yellow fibers in the subendothelial layers. The tunica media

is very much thinner than the corresponding coat in the arteries, and instead of containing muscular tissue with great quantities of elastic tissue, it contains a few muscular fibres, but the main bulk of the coat is made up of white fibres. In the large veins near the heart the few muscular fibres which do exist are replaced by straited muscular fibers corresponding in structure to those of the heart. The tunica adventitia exists in the veins as in the arteries, but is much thicker and heavier here. It is composed of fibrous and elastic tissue with some bundles of longitudinal fibers near the surface.

Valves exist in the veins while they are entirely absent in the arteries with the exception of those found at the beginning of the aorta and the pulmonary artery. The valves found in the veins are very similar to those of the arteries just mentioned, in that the cusps are formed by little pockets as they are in the semilunar valves, but instead of there being three of these cusps there are only two. The cusp is formed by a thin extension of subendothelial tissue covered by endothelial cells projecting itself into the lumen of the vessel. These valves are usually arranged in pairs, or possibly several of them close together. In veins of less than one-twelfth of an inch in diameter they are not found as a rule, nor are they found in those veins which are not subject to pressure. They are found in the veins of the extremities principally, where the continuous contractions press upon the vessels and tend to force the blood back from whence it came. The valves, however, prevent this and serve to always insure a forward movement of the blood. Valves are not found in the superior or inferior venae cavae, in the pulmonary veins, unbilical vein, the veins of the cranial cavity or spinal canal, nor in the veins of bones.

Capillaries are found in practically every part of the body with the exception of the spleen, the placenta and parts of the penis. Every arterial plexus is connected with every venous plexus by these minute capillaries. In size they vary from one

two-thousandth to one five-thousandth of an inch in diameter and average about one-fiftieth of an inch in length. In the skin, the lungs and in bone the capillaries are largest, while in the brain and in the wall of the intestines they are smallest. The meshwork of the capillaries is differently designated according as to whether the interspaces are of one shape or another, and the shape of the interspaces depends largely upon the type of tissue which is being supplied. Thus in muscle where the fibers are parallel the capillaries are also parallel, and are joined by little cross branches, making the shape of the space elongated or paralelogram. In the lungs, on the other hand, there is no regular arrangement of the cells and the interspaces here are rounded.

So we have two kinds of capillary meshwork; the elongated and the rounded. In some parts of the body there is a very rich supply of blood because the capillaries here are very widely distributed, while in other parts of the body the capillaries are comparatively scarce. In general it may be said that the vascularity of a part depends upon the activity of that organ. Thus the lungs are very richly supplied while bone is comparatively poor in blood.

CHAPTER XXIV

PROPULSION OF BLOOD

Elasticity of the Arteries

Every time the heart contracts it forces out a quantity of blood into the arterial vessels (about three ounces). If the arteries were hard inelastic metal tubes, which did not admit of any dilatation the blood would be forced out from the periphery of the arterial system as rapidly as it was forced in at the root. This, however, is not the case. We have in the study of the arterial wall noted that there were many elastic fibers intermingled with the muscular coat, as well as being widely distributed in the tunica adventitia, and this fact gives to the arterial wall the quality of elasticity. When the ventricles contract and force the blood into the arterial system, instead of its being forced out at the periphery at the same rate, the walls stretch, and thus a certain amount of the kinetic energy expended by the ventricles is stored up in the arterial wall as potential energy. This potential energy exerts itself at all times, because the vessel walls are always on the stretch and always tending to force the blood from their cavity to the cavity of the veins where the pressure is lower.

It can readily be seen from the foregoing that there is a sudden variation in the blood pressure when the ventricles contract and this variation is carried along the arterial system from origin to termination in the capillaries. This is known as the pressure wave or the pulse wave, and it becomes in volume less and less as it gets further and further from the aorta, where it is greatest. In the small arterioles then it is hardly noticeable, and in the capillaries and veins it cannot be felt, except as it may exist as

a back pressure from the auricles into the larger veins which are not protected by valves. This pulse wave, which is the result of the ventricular contraction, is expressed in several different ways. First, in an increased blood pressure; second, an increase in the velocity of the blood. (This, of course depends upon increase of pressure.) Third, the pulse wave causes a change in the vessel wall through which it is passing, which change may be visible or at least palpable. This physical change in the vessel wall is commonly termed the pulse, and in placing the finger on the radial artery it is not the pulse wave which we feel. It is the thickening and hardening of the arterial wall to withstand the pressure of the oncoming wave. This hardening progresses at the same speed as does the pulse wave.

The sphymograph is an instrument used in making tracings of the variations in pressure in the blood vessels, and is especially useful in studying the pulse. It is this instrument that has taught us that the variation in the pressure known as the pulse wave in reality travels from the origin of the arterial system to the periphery. The sphymogram is the record of the tracings made, and when studied shows that there is a second rise of pressure after the primary rise, and that between these two there is a decrease. This is known as the dicrotic pulse, and there have been various explanations advanced as to its cause. It is absolutely established that the secondary rise is due to a wave traveling in the same direction as the primary, because the two are always approximately the same time apart, and if traveling in opposite directions this could not be the case.

The idea is often advanced, and is held by some investigators even today, that the second rise is due to a reflection of the pulse wave, from the peripheries of the arteries, and their bifurcations, back to the semilunar valves, where they again start on their course through the arterial system just behind the primary impulse. It is hard, however, to realize how this could occur, as the peripheries of the various arteries are different dis-

tances from the semilunar valves, as are the bifurcations, and to conceive of how all these reflections might be joined to form one pulse wave, is difficult to say the least. A much more feasible explanation is that the arteries act merely as any elastic tube. If an ordinary thin rubber tube is filled with water and a quantity of water is forced in at one end of the tube, a wave is set up toward the other end, but immediately behind this first wave, which has caused a distention of the rubber wall there is a short area where the diameter of the tube is smaller than it was in the beginning, and this may be accounted for by the elastic recoil of the rubber, returning, as a pendulum, after it has been stretched, to a condition below the original. If this occurs in rubber which possesses the quality of elasticity it also occurs in blood vessels, because they also are elastic. Aiding the natural rebound of the elastic wall after the first wave has passed along the vessel, we have here an additional factor. Immediately after the blood is forced into the aorta from the ventricle, and the pressure in the aorta is correspondingly raised, the cusps of the semilunar valve return to their position of apposition in the lumen of the vessel, and in so doing, allow a little blood to get back into the ventricles; also the cusps of the valves bulge into the ventricles, and thus relieve some of the aortic pressure. This condition following just on the heels of the first wave, gives rise to a negative wave which is registered on the sphygmogram as the drop in pressure between the first and second waves. The second pressure wave then is merely the oscillating of the vessel wall, aided by the action of the semilunar valves in magnifying the depression after the primary wave.

Pulse Rate.—The frequency of the pulse varies under different conditions and at different ages. In foetal life the rate is about 140 per minute; during the first year, from 120 to 140; at the tenth year, about 95; at the fifteenth year, about 75, and in adult life, from 70 to 72. This rate of pulse remains till about the age of sixty, when it gradually decreases to about 60. It must

be understood that these figures are merely averages, and that in normal individuals the pulse may be as low as 55 or as high as 87 per minute. Exercise increases the heart action, and after a reasonable exercise has been taken, such as running for a short time, the pulse increases about 30 beats per minute. The pulse is faster in the standing position than in the sitting, and faster in the sitting than when the individual is reclining. The pulse is increased during inspiration, during forced breathing and upon the consumption of foods and liquors. A high external temperature increases the heart beat, and any mental excitement produces the same results. It is a known fact that the pulse of a woman or child is more susceptible to mental variations than is that of the man. Another important factor to consider in the study of the pulse rate is the fact in the normal woman that it is usually about 8 beats in excess of that in the normal man.

Rapidity of the Pulse Wave

By using two sphygmographs and causing their writing points to record on the same paper placed on a revolving cylinder, and attaching the ends of them to different parts of the arterial system, it will be found that they record the pulse wave at different periods. Now a computation must be made showing the distance apart in the arterial system of the two sphygmographs. By this means it may be determined how fast the pulse wave travels. The results obtained show that a pulse wave is propagated at the rate of about 25 feet per second in the lower extremities and about 22 feet per second in the upper extremities. This difference is due to the difference in the distensibility of the vessels in the two localities, those in the upper extremities being more distensible. During sleep the rapidity decreases to about 22 feet per second in the lower and 19 feet in the upper extremities. The rate of propagation increases in arterio sclerosis, because of the decreased distensibility of the arterial walls, and in chronic nephritis or any disease where there is an increase in the blood pressure. This is because of the fact that any increase in the blood

pressure, due to an increased amount of blood, an increase in the peripheral resistance, or any other factor, serves to stretch the elastic arteries, and this tends to decrease the distensibility.

The rate of propagation of the pulse wave should not be confused with the velocity of the blood, for the former is many times faster than the latter. The pulse wave may be favorably compared to the ripple on the surface of a body of water which occurs independent of the current of the water. This is well illustrated in noting that the ripples on the surface of a river may flow in the opposite direction from the current, or, if flowing in the same direction, are entirely independent of the rapidity of the current. Of course, the pulse wave as compared with the ripple is not entirely analogous, for while the latter may occur in any direction, and is usually not so fast in comparison, the pulse wave always occurs in the one direction from the heart to the peripheries of the arteries, and travels much faster than the blood. In brief, we may say that the pulse wave is merely a wave formed by the change of the position of the molecules forming the blood, and this change occurring in rapid succession along the course of the vessel.

CHAPTER XXV

PRESSURE IN BLOOD VESSELS

Arterial Blood Pressure

Various apparatuses have been developed for the measuring of blood pressure both in animals and in man. In animals a mercurial manometer has been directly attached to the arteries which are accessible, and the height to which the mercury rises in the small glass tube indicates the pressure. This method, however, must give rise to some variations, for the pulse wave is recorded at each contraction of the heart, and the same record is produced here as in the sphygmograph tracing. The investigator must, however, strike an average pressure, which is done by noting the greatest pressure indicated and the lowest pressure indicated. This may be registered by the use of a revolving cylinder, as in the other experiments, and the line which the maximum pressure produces at each contraction is called the line of maximum pressure, while that joining the minimum pressure points is known as the line of minimum pressure. The line of mean pressure is then drawn so that between it and the line of pressure variation the same area lies above as below. It must be borne in mind that the blood pressure varies under different conditions, but experiments have shown that in warm blooded animals the pressure varies from 100 to 200 mm. of mercury. In cold blooded animals it is not so high, seldom being more than 50 mm. and sometimes even lower. The blood pressure and its average height seems to be a peculiarity of the different species, as there seems to be no difference in it dependent upon the size of the animal or the rapidity of the heart beat.

In man the blood pressure is measured by means of the

sphygnometer attached to a mercury manometer. We will not go into the description of this instrument except to say that it is attached over the arteries which are near the surface and produces a graphic record of the variations. The accuracy of this method is assured because in animals it is found that it gives the same results as when the apparatus is attached directly in the blood stream. When sitting in an easy position it is about 125 mm. of mercury, while in the recumbent position during sleep or rest it may fall to as low as 95 mm. Muscular effort raises the blood pressure in the arteries, partly as an adaptative method, and in some forms of work (such as lifting), because of the contraction of the muscles occluding the foramina of small vessels, while the blood in the veins is continually being forced on into the heart and into the arterial system. At such times the arterial pressure may rise as high as 180 mm. of mercury, and so it can readily be seen that in such event harm might be done to the valves of the heart, or even a hemorrhage might be caused in the weaker vessels. These findings have been given, based upon readings while the sphygnometer was attached over the brachial artery, and it should be remembered that the pressure in arteries nearer the heart is greater while in those farther away it is less. The pressure in the pulmonary artery is only about one-sixth of that in the systemic system.

Factors Which Alter the Arterial Pressure

An increase in the rate of the heart beat or an increase in its power tends to raise the blood pressure because at that time more blood is forced into the arterial system, and if the peripheral resistance remains the same the arteries become engorged and the pressure is thus raised. An increase in the peripheral resistance tends to raise the blood pressure, providing the heart maintains its normal rate and strength, because the blood is dammed back into the arterial system and a greater pressure is required to force it out at the same rate at which it is being taken in. An increase

in the total quantity of blood raises the blood pressure, not only in the arteries but in all parts of the vascular system, and this because it of necessity causes a greater distension of the vessel walls, and more pressure is thus exerted by them. The arterial blood pressure is decreased by a decrease in the rate or force of the heart beats, by a decrease in the peripheral resistance and by a decrease in the total amount of blood in the vascular system. This latter condition may exist after hemorrhage, where a quantity of blood has been lost, although a normal mean blood pressure is soon established, providing the hemorrhage has not been too great, by the transmission into the blood stream of fluid from the lymphatic and serous circulations.

Factors Which Alter the Venous Pressure

An increase of the quantity of blood increases the venous pressure as well as the arterial. In fact the effect on the venous pressure is more lasting than that in the arterial. This is because when the blood is increased, Innate becomes aware that the distensibility on the arteries cannot be carried to the same extent as in the veins, and as a result the impulses of the vaso motor nerves are decreased, and the peripheral resistance is decreased. This allows the blood to flow on into the easily distensible veins, where it is accommodated, but at the same time causes a rise in pressure here.

An increase in the rate of the heart beat or in its force causes a decrease in the venous pressure. This is for the reason that the blood which is forced on into the arterial system at a more rapid rate is taken from the venous system, and the gain which is made in the arteries must be accomplished at the expense of the veins.

An increase in the peripheral resistance causes a decrease in the venous pressure because when the arterioles are constricted the blood becomes dammed back into the arteries, and cannot flow into the capillaries and thence to the veins at the same rate as it did before. At the same time the heart begins to pump more

forcibly as an adaptative measure to increase the pressure in the arterial system to such a degree that it may pass on into the veins at the proper speed. This draws more blood than ever from the venous system, and as a result the pressure here is markedly decreased. This condition does not continue indefinitely, however. Soon a point is reached where the increase in the distensibility of the arterial wall has reached such a degree that it is successful in forcing the blood out at the periphery at the same speed at which it is being supplied from the heart. However, if the peripheral resistance is very markedly increased it may be that the heart is unable to overcome the pressure existent in the arteries as a result of it, and in that event the blood is dammed back into the venous system. The only permanent effect of this condition, however, is a slowing of the blood velocity in the vascular system as a whole.

Factors Which Alter the Capillary Pressure

Capillary pressure is increased by a decrease in the peripheral resistance, thus allowing the pressure of the arterial system to be more readily propagated to the capillary network. It is also increased by the decrease in the size of the lumen of the venules leading from the capillary area, in that the blood cannot escape as fast as it is being supplied from the arterial system, and till such a time is reached when the capillary pressure is sufficient to overcome this increased resistance it continues to rise. The capillary system, lying as it does between the arterial and venous system, is affected by any changes in arterial or venous pressures; a rise in either causes a capillary rise, and a decrease in either causes a capillary decrease. It must be remembered, however, that between the arteries and capillaries there is the peripheral resistance which offers itself as a partial obstruction, so that changes in the arterial pressure do not so quickly produce a change in the capillary system as does a like change in the venous system.

It is interesting to note that a continued excessive pressure

in the venous system, and propagated from it to the capillary system is a frequent cause of dropsy. (Cardiac dropsy.) In this event the blood is dammed back into the thin walled capillaries and their walls become distended so that they admit of passage of more serous fluid than should in the normal vessel be expelled. Not only does this effect exist, but the entire venous system being affected (in case of cardiac dropsy) the thoracic and right lymphatic ducts have to discharge their lymph against higher pressure, so they cannot carry away the excessive fluid in sufficient quantities to accommodate the excessive formation.

CHAPTER XXVI

THE VELOCITY OF BLOOD

In the study of the pulse we have determined that at each contraction of the ventricles there was a pressure wave propogated along the course of the arteries, and that this pressure wave was characterized by a change in the position of the molecules, and by a suddenly increased pressure, but that it merely indicated the maximum pressure in the artery, and that there always existed a mean pressure. This same idea may be carried to the subject of velocity. At the time the pressure wave is passing along the course of the arterial system there is an increase in the amount of blood which is present in each section of the vessels as the pulse wave passes. If there is a dilatation of the vessel there must be an increase in the amount of blood. This wave, known as the pulse wave or pressure wave, assumes another feature, and we may call it the velocity pulse. This does not mean that it corresponds to the velocity of the blood, any more than the pressure existent while the pulse wave is traversing the arteries may be called the arterial pressure.

In the measurement of the blood velocity there are many considerations to be dealt with. To best show the factors which may be involved we may first consider the velocity of a river. If every particle of water in the river maintained the same speed we might time one particle at two given points, and by computing the time occupied in traveling from the one to the other a conclusion might be arrived at which would indicate the velocity of the river or any part of it. This, however, could not exist unless the river flowed at a uniform rate throughout its entire extent. If the velocity was different at different parts then we could

only state what the average speed was. Thus far we have not considered that a river has a bed, over which it flows, and with which its particles produce friction. It is because of this fact that the water in the center of the stream flows faster than that at the sides. The only way in which we may arrive at a conclusion as to the average rate of speed for the river body, is not by measuring the rapidity of any given part of the water, but by determining the cross-sectional area of the stream, and the volume of water which is passing a certain point in a certain time. Now, by dividing the volume of water by the cross-sectional area we determine the rate of flow in a given time. These statements as to the obstacles to be overcome in measuring the velocity of water are given in order to show those which are met with in the study of the velocity of the blood stream.

In the study of the blood flow it must be borne in mind that there is resistance offered to the onward propulsion of blood, by the friction of the walls over which it has to pass. Just next to the wall of the vessel there is a layer which adheres closely and does not move to any appreciable degree. In contact with it is another layer which adheres to the first, but as the first layer does move in the very slightest, the second layer does not meet with the same resistance as does the first. The third layer, in turn, has only the resistance of the second layer to overcome, and this is not as great as the first, and so the rapidity of the third layer is greater than either the first or second. This comparison may be carried out to the very core or axis of the blood stream, each concentric layer of blood flowing slightly faster than the layer just outside it, until in the center of the stream we have the greatest speed, and this is called the axial stream. That part of the stream which lies near the wall of the blood vessel is called the plasma layer, although between it and the axial layer there is no definite line of demarcation

Again comparing the blood stream to a body of water flowing through a given channel we may say that the velocity of a

river increases as the size of the bed through which it has to pass is decreased, and that when it widens out into a large lake the velocity is greatly lessened. The same may be said of the velocity of blood in the vascular system. When the bed of the stream increases the velocity decreases, and as the bed of the stream in the vascular system is the cross-sectional area of its vessels we may say that when the cross-sectional area increases the velocity decreases. As an artery such as the aorta divides, however, it should not be supposed that its cross-sectional area decreases, because the lumen of a branch is smaller, but it must be considered that all these vessels are carrying blood given them from the aorta, and that their combined cross-sectional area should be compared to the cross-sectional area of the aorta. Viewed in this light it is found that throughout the entire arterial system the bed of the stream is increasing as the vessels are further removed from the heart, because the combined cross section of the branches of any artery is greater than that of the mother artery. It can readily be seen that the velocity of the blood must decrease as we leave the heart and approach the capillary system, because there is continually an increase in the size of the bed through which it flows. Finally, when it reaches the capillaries it has reached the widest part of the vascular system, and from this point on it begins to increase in velocity because the bed through which it is flowing begins to decrease in size. As the capillaries join to form venules, and these join and rejoin to form larger veins the cross-sectional area of the vessels decreases until finally the large superior and inferior venae cavae are reached, and it is here that the velocity of the blood is greatest in the venous system, although even here it is not so fast as in the aorta and pulmonary artery of the arterial system.

Difficulty is often encountered in realizing why the velocity does not correspond to the pressure. Difference in pressure is the primary factor that causes any velocity to be present in the blood, for if it were not for this important factor the blood would

not change position. Velocity, however, depends, as we have shown, upon the size of the bed through which it is passing, and to some degree upon the friction to be overcome in passing over the vessel walls.

It must be borne in mind that in moving liquids there are two kinds of energy present. Potential energy is inactive energy, such as that expressed by the arterial walls, when they are on the stretch, because of being filled with blood from the contracting ventricles. The potential energy of the arteries is measured by the lateral pressure of the blood, which is merely the expression of the degree of stretch which exists. Kinetic energy is an active energy and is expressed in the blood by the change in position of the molecules of blood. If, then, the blood changes its position rapidly, (velocity) the kinetic energy is greater than as if the change were slower. In brief, the velocity of the blood expresses the kinetic energy. As the blood approaches the periphery of the arterial system, the velocity of the blood becomes less and less, therefore the kinetic energy must become correspondingly less. The question arises, what becomes of this energy? Where does it go? It is expelled in the form of heat, from the friction of the blood on the arterial walls. and it should be remembered that especially from the small arteries to the capillaries this friction rapidly increases; therefore the kinetic energy and velocity rapidly decrease. The potential energy is also drawn upon and part of it transformed to kinetic energy to overcome this friction. In the capillaries the velocity of the blood is least, and so the kinetic energy must be least at this point. However, from the capillaries to the heart the velocity increases, and therefore there must be an increase in the kinetic energy. Where does this energy come from? A certain amount of it is drawn from the potential energy, and it is found that as we advance along the venous system that the lateral pressure and thus the potential energy are decreasing. Further than this the heart by contracting and forcing the blood into the

ventricles is producing a suction influence upon the blood, thus producing kinetic energy. The respiratory action serves to transform part of its force into kinetic energy, and any muscular action in the body which presses upon veins, tends to force the blood on instead of backward, because of the valves, and these additional actions all tend to establish a greater kinetic energy and thus a greater velocity.

The velocity of the blood may be measured by various apparatuses which have been evolved for that purpose, but we are not especially concerned with the construction of these different instruments. The results arrived at in different animals are widely different, and the velocity in different parts of the vascular system is variable. Also there is a variation in the different parts of the stream of blood; that in the center moving most rapidly, while that forming the plasma layer moves most slowly. The average mean velocity of blood, however, in the large arteries is probably not more than 20 c. per second, nor less than 10 c. per second. It should be remembered that the velocity rapidly decreases as the capillary area is approached, and then increases again as the blood progresses toward the heart through the veins.

Peripheral Resistance

As has already been stated the arteries divide and subdivide until finally the terminal arteries are reached, and from these terminal arteries are given off arterioles, which in turn empty into the capillaries. There is a histological difference between the capillaries and the arterioles, which is important in governing the blood flow. In the capillaries there are endothelial cells which form the wall of the vessel, and they are joined together by cementing material. There are, however, no other layers in the capillary wall. In the arterioles, on the other hand, there are muscular fibers arranged in a circular manner, so that when they contract they will decrease the lumen of the vessel and thus offer more resistance to the blood of the arterial system. This

resistance is known as the peripheral resistance, because it is found at the periphery of the arterial system. The capillaries because they have no muscular fibers in their walls, do not alter their shape except as they are forced to dilate or allowed to collapse by the excess or want of blood.

CHAPTER XXVII

CIRCULATION IN BLOOD VESSELS

Capillary Circulation

The capillaries in different parts of the body vary in size, being 5 to 25 micromillimeters in diameter, but while there is this remarkable difference in their size and that of the larger arteries, still it must be remembered that there are many more capillaries than there are of the arteries, and that in reality the total cross sectional area of the capillaries is about 500 times as great as that of the aorta at its narrowest point. If the difference is so marked in regard to their cross sections, then the variation in their velocities must be widely marked.

In the capillaries of some parts the circulation may very easily be viewed with the microscope. Here the speed is variable, but may be said to average about 1/20 of a mm. per second. Another peculiarity of the circulation in the capillaries is the fact that the pulse is obliterated here, because of the peripheral resistance in the arterioles. Here we have the same principal applied that exists in the larger vessels, as to the variation of different parts of the stream in their velocities. On the outer walls there adheres a layer of plasma, which because of the great resistance offered by the capillary wall, moves very slowly. This is known as the still layer, or the plasma layer, of the blood. Just inside this slowly moving layer is a layer of white blood corpuscles which moves more rapidly than does the plasma layer, but still not as rapidly as does the central stream which is composed of red blood corpuscles. This axial stream of red cells moves more rapidly than any other part of the stream, but because the vessels

are so small and the red cells are comparatively large, the shape of the corpuscles must be changed into various forms in order to allow for their passage. It is interesting to note that between the cells forming the wall of the capillaries are small spaces filled with cementing material. These spaces are known as pseudostomata and through this cementing material which fills their lumen, the white blood corpuscles pass, opening a passage ahead of them which closes immediately after their passage.

Venous Circulation

The circulation of blood in the veins gives rise to the possibilities of using instruments to determine the blood pressure in different parts. Here, as in the arteries, it must be remembered that the pressures vary considerably, dependent upon what part of the venous system is being observed. It is obvious that the pressure is lessened as we near the heart, because if this were not the case the blood would not flow in this direction. Instruments have been devised for the measurement of the venous pressure and it is found that in the veins of the arm and hand the pressure varies from 3 to 8 mm. of mercury. It must be borne in mind, however, that this measurement must of necessity vary with different positions, because gravity always affects the venous pressure. It also varies with the variations in the amount of blood, rapidity of the heart beat, change in the peripheral resistance, etc. In cases where there is a congestion of the venous system the pressure in the veins of the arm and hand may rise as high as 15 mm. of mercury.

Regularity of the flow in the venous system would be expected because here the pulse is eliminated, and it will be remembered that this is the potent factor in causing a variable velocity in the arterial flow. This, however, is not the case, and in fact the blood in the venous system flows with less regularity than in the arterial. This is because the blood in the venous system does not depend entirely upon the potential energy imparted to the

arteries at the termination of the ventricular systole, for the force to drive it on. Rather its force is derived from the suction action of the heart, which when it forces the blood from the auricles to the ventricles, then relaxes and sucks upon the blood in the venous system; also the respiratory movements of the thorax aid the onward flow of blood in the veins. When an inspiration is made the intrathoracic pressure is lowered and thus the auricular and venous pressure is lowered and as a result the blood is sucked into the auricles and veins of this large cavity. Further than this every movement of the muscles of the body which might in any way tend to exert a pressure upon the venous wall, serves to push the blood on toward the heart, because the valves prevent it from going backward. These factors then are the causative features which produce the movement of blood in the veins, and it is because the blood here must depend upon so many different factors, all of which alter under different conditions, that the velocity of the blood in the veins is so irregular.

Pulse in the Veins

In the veins it is sometimes found that a pulse may be detected, especially in the very small veins and venules. When this is the case and the pulse cannot be found in the larger veins, it is because it is propagated through the capillary system, and this in turn is due to a greatly lowered peripheral resistance. However, a pulse can usually be felt in the jugular veins of man, while in a state of health, and in this event it is due to the contraction and sudden rise in pressure in the auricles, causing a pulsation which is forced back against the stream of the blood in the veins. The valves and the widening of the total cross sectional area of the veins, as the distance from the heart is increased, explain why this venous pulse may be felt in the large veins near the heart, while not in the smaller veins further away. Sometimes where a vein lies closely in relation with an artery and the arterial pulsation is transmitted to the wall of the vein, there appears to be a pulsation due to a pulse wave in the vein, but in reality this is not

the case. Pathologically there is the venous pulse, but this does not occur at the time the auricles contract, but rather when the ventricles contract and is due to the inability of the tricuspid valve to prevent regurgitation into the right auricle.

The Circulating Period

Various estimates have been made in regard to the length of time it takes to complete a circulation in the human body, and here as in other questions, experiments have been made on the lower animals. The results arrived at lead us to believe that the pulmonary circulation in man takes about 12 to 15 seconds. Computations point to the fact that in the systemic circulation the average time required is about 60 seconds. This, however, can only be approximated, as the different courses through the circulatory system are practically unlimited, and while a particle of blood is passing out of the aorta and thence to the coronary artery and back to the heart by means of the coronary veins, another particle of blood might pass to the lower extremities from the aorta, and wind through very tortuous courses and return to the heart long after the first had arrived. It can readily be seen then that at best the length of time which is taken to complete a circulation is hard to estimate, and that a general computation is all that can be made.

CHAPTER XXVIII

INNATE CONTROL OF THE CIRCULATION

Innate Control of Bloodvessels

It is known that the blood vessels are composed of several walls, one of which is muscular in structure, and that the size of the lumen of the vessels may be altered, dependent upon the constriction or relaxation of these muscle fibers. It has not been definitely proven that the lumen of the veins, except the portal, may be altered, but experiment has led to the proof that this change does occur in the arteries. The muscle fibers of the arteries are supplied with nerves, one set of which has the power of transmitting impulses of relaxation, and this is known as the vaso-dilator set, while those which have to do with the transmitting of contraction impulses are known as the vaso-constrictor nerves. Both of these nerve fibers come under the head of vaso-motor nerves because they transmit impulses which control the muscular action of the arteries. While these nerves are of the efferent class, they act dependent upon the interpretation of impressions carried to the vaso-motor centers by afferent nerves. These nerves also may be divided into two classes, first those carrying impressions which when interpreted give rise to an action of the vaso-constrictor efferent nerves and thus raise the blood pressure; these are known as the pressor nerves. Second, those carrying impressions which when interpreted give rise to an action of the vaso-dilator efferent nerves and thus lower the blood pressure; these are known as the depressor nerves. While it is true that the action of the efferent nerve is dependent upon and effected largely by the interpretation of the impressions sent to the vaso-motor centers by the afferent nerves, still there are some

the case. Pathologicall... not occur at the time ... ventricles contract and is ... to prevent regurgitation ...

Various estimate... time it takes to com... as in other question... animals. The ... monary circula... tations point ... time requir... approximat... system are ... passing ... back to t... of blood ... wind th... after t... best th... hard ... be ma...

... after the interpretation of these

... case of adrenalin, the active prin... which by its presence preserves ... and when in excess causes a hyper... arterial pressure. Certain other ... endings so that there is a complete ... arterioles and a marked decrease of ... seems that the small arteries and ... by the activity of the vasomotor ... of the arterial system, while the ... any way. This is due to the absence ... coat. The following are some of ... the conclusion of the innate vaso... pressure by means of the action upon ... arteries.

... with it will be found that in ... capillary area may be observed, the ... resistance to the progress of blood ... is indicated by the change in color ... the tissue becomes a dark pink color it ... of blood in the capillaries and if it ... indicates a lack of blood in the capil... color are due to the contraction or ... fibers of the arterioles.

... the temperature indicates the changes in ... and if the arterioles are allowed to dilate ... in the capillary area, while if the ... the temperature is decreased. This ... the fact that the temperature of the ... of the trunk is higher than in the super... extremities, and if less obstruction is offered ... the capillary areas, it retains more of its

original high temperature, while if more of an obstruction is offered the blood loses more of its original high temperature.

If the blood pressure in the artery and the vein supplying a certain part is measured at the same time, and artificial stimulation is applied to the vaso-motor nerves supplying this area, the changes in the pressures recorded would indicate that variation was present in that particular area. For instance, if upon stimulation of a certain nerve leading to the area under observation, the arterial pressure was raised, and the venous pressure lowered, the only conclusion which could be drawn would be that the circular muscles of the arterioles had contracted and were damming back the blood into the arterial system, and at the same time depriving the veins of their proper supply. If, on the other hand, the venous pressure was raised and the arterial pressure lowered, the only conclusion would be that the peripheral resistance had been decreased and the blood in the artery allowed to pass on into the vein. Other experiments are used, such as measuring the velocity in the blood in a part and allowing it to indicate the peripheral resistance offered to the onward flow, or possibly by measuring the volume of a part and drawing a conclusion from the results obtained, as to the amount of blood with which it is being supplied. However, the methods of investigation are not so important to us as the results obtained, and we will pass on to the study of the latter.

Innate Vaso-Motor Nerves

From the upper spinal nerves, both vaso-constrictor and vaso-dilator fibers pass to the region of the head. This is proven by cutting the superior branches of these spinal nerves and noting that the ear on the altered side becomes very red, and that many of the veins show a great dilation, proving that the peripheral resistance must have been decreased in order that this dilation could be accomplished. Now, if the peripheral ends of the sectioned nerve fibers are stimulated, the part becomes pale and

...strictor fibers are again acting from ...the peripheral resistance is again assert- ...that when these changes are made ...the mouth on the affected side first ...the peripheral nerve is stimulated it ... This is exactly the opposite condition ...serves to indicate that the mucous ...vaso-dilator fibers from the cervical ...fibers from the spinal nerves do not ...vessels, but after entering the cranial ...the cranial nerves and thus reach the ...has a greater influence upon the ...region than any of the other cranial

...that Innate Intelligence shall have a ...the blood supply to different parts of the ...the blood supply that when an organ or ...receive a large quantity of blood, while at ...inactive, its proportion of blood is ma- ...should be borne in mind that the blood is ...wherein we find serum, and as it is in the ...properties are carried, the regulation of ...regulates the amount of nutritive materials. ...organ is active more nutrition is re- ...cells may be built up by Innate at the same ...torn down. Further, when an organ is ...oxygen, and as this important element is car- ...we have another reason why the blood ...creased. There are times immediately after a ...greater blood supply to the abdominal viscera, ...the process of digestion goes on, and while ...ceased there is a greater katabolistic process ...other times. When strenuous mental pro- ...accomplished the blood supply to the brain tissue

is great and it is a known fact that immediately after a meal the mental efficiency is not so great as when the digestive organs are at rest. This remarkable control which the Innate Intelligence exercises over the blood supply to all parts of the body is accomplished by sending impulses over the nerves known as the vaso-motor nerves, either of the vaso-constrictor or the vaso-dilator types.

The question often arises as to whether or not the arteries of the brain are supplied with vaso-motor nerves, and while some investigators dispute their existence in this region, it seems more reasonable to presume that they as well as other vessels of the head are so supplied. Certain it is that adrenalin produces the same effect here as in the vessels of other parts of the body and this would serve to indicate that the muscular fibers are present in the bloodvessels of this part as in any other, and are under the control of Innate Intelligence through the vaso-motor nerves. One of the arguments advanced against the existence of innate control of the arteries in the cranium is the fact that the vessels, together with the brain, are enclosed within solid walls, which will admit of no change in size of the soft tissues contained. However, it must be remembered that the different parts of the brain have different functions and that when one part is functioning, another part may be at rest, and thus would not call for the same quantity of blood as the first. With this feature in mind it would seem even more essential that each area should be regulated differently, and this would call for even a more delicate regulatory apparatus than would be required in other parts. Innate does not utilize all parts of the brain as agents through which to send out mental impulses with like degree of rapidity. In certain forms of labor where the arms are being used strenuously, those centers of the brain from which Innate starts mental impulses to this region is kept very active, while the area which is concerned especially with the legs, may be comparatively inactive. We may conclude then that there can be as many different areas of the brain distinguished one from the other, as there are different

parts of the body, and that the blood supply to these different parts of the brain is regulated according to the interpretation which Innate places on its various needs.

From the thoracic gangliated cord are given off many vaso-motor nerves through the splanchnics, and it is found if there is a section made of these nerves, that the vessels of the abdominal viscera supplied by them become engorged with blood, due to the relaxation of the circular fibers of the arterioles. The splanchnic nerves supply such a large part of the abdominal viscera that a dilatation of the vessels of all this area decreases the arterial blood pressure in the entire vascular system. Now if the peripheral ends of the cut splanchnic nerves are artificially stimulated, the vessels soon regain their normal condition and the blood pressure in general resumes the normal degree. There is no doubt but that vaso-dilator fibers are present in the splanchnic nerves as well as vaso-constrictor, and certain peculiarities lead to their demonstration. For instance, after a nerve has been cut the vaso-constrictor lose their excitability sooner than the vaso-dilator fibers, and so after a certain time has elapsed the latter respond to stimuli, while the former do not. If the nerve is cooled, the vaso-dilator fibers retain their excitability after the vaso-constrictor fibers have become unable to respond. With these facts in mind it is easy to demonstrate the presence of vaso-dilator fibers in the splanchnic nerves, although it must be admitted that they are not present in such great numbers. The brachial nerve in the upper extremities and the sciatic nerve in the lower extremities contain both types of vaso-motor fibers, and this fact is proven in these areas, just as in the cases of the head and the splanchnic areas.

The question arises as to whether there are vaso-motor nerves which supply the venous walls as well as those of the arteries. In the case of the portal vein the walls are supplied with vaso-constrictor fibers from the splanchnic nerves, as are the arteries of the splanchnic viscera, but care should be taken in assuming this as a criterion of the other veins of the body. This because the portal vein is in many respects like an artery, breaking up into

branches and then into capillaries. Whether the veins in other parts of the body are so supplied, is a question, but experiment would seem to point to the fact that vaso-constrictor fibers are very scantily supplied to some of the veins. It is not reasonable to suppose that vaso-motor fibers are supplied to the veins of the body to any marked degree, because there apparently is no necessity for them. Innate is equipped on every hand with controlling impulses which she sends to all parts of the body as they may be required, sending out impulses of secretion motor, nutritive, etc., to those parts where they are necessary. We would hardly expect, however, that Innate would send impulses of secretion or motor impulses to a bone cell. As the veins are merely a drainage system for the arteries, there is no necessity for their size being altered, and in all probability the motor fibers supplying them are very few, if present at all.

Vaso-motor fibers exit from practically every intervertebral foramen in the spine, coming from the cord by means of the anterior roots; from here the fibers pass by means of the white rami communicates to the ganglia of the sympathetic chain, and from here are distributed to the body by the large nerves which we have mentioned.

VASO-MOTOR CENTERS

Located in the medulla oblongata is an era known as the main vaso-constrictor center, and it is through this center that Innate has a great control over the peripheral resistance. There undoubtedly are some vaso-constrictor centers found in other parts, but these are relatively unimportant. The problem presents itself here as to whether Innate sends out vaso-motor impulses because of the receiving and interpretation of efferent impulses, or whether the condition of the blood has the control in hand.

Let us review the data and draw our conclusions. Innate receives the knowledge of necessity of a more rapid supply of oxygen to the tissue cell by an interpretation of the impressions

transmitted over the depressor nerves. Impulses are then sent out over the vaso-inhibitory fibers, the circular fibers of the arterioles are relaxed and the blood sent through the capillary area more rapidly. Again the blood becomes laden with carbon-dioxide, and according to those who support the theory that blood has the control in hand, this blood comes in contact with the brain cells and Innate becomes aware by this means of the fact that more oxygen is needed. It is, however, not logical to assume this latter viewpoint, because, were the order of things entirely reversed, and were it admitted that Innate did gain her knowledge of the deficiency of oxygen from the fact that the blood came in contact with the brain, there would still be no means whereby she could become aware of what parts were deficient in oxygen and what parts were receiving the normal supply. This knowledge can only be gained by interpreting the impressions which are continually coming to the brain from all parts of the body over the afferent nerves.

INNATE CONTROL OF THE HEART

The same conditions prevail in the control of the heart as we have indicated in the blood vessels, namely the existence of both an inhibitory and an accelerator set of nerves. In experiment, if the former are stimulated, there is a marked decrease in the rate or strength of the heart beat, while if the latter are stimulated there is an increase in the rate or strength. The Innate Intelligence resident in the brain sends out impulses over the cardio-accelerator or cardio-inhibitory fibers, because she receives impulses from all parts of the body over the afferent nerves which call for this increase or decrease in activity. Various conditions may call for this change. Perhaps the inability of the lungs to obtain enough oxygen, perhaps the call of all the tissues of the body for an increase in the amount of oxygen, or a variety of other conditions, may demand an increased or decreased activity of the heart, and as a result it will be regulated by impulses sent over the accelerator or inhibitory nerves.

CHAPTER XXIX

VASCULAR SYSTEM OF THE FOETUS

The blood in the foetus circulates in a peculiar manner, both in the blood vessels and in the heart, and this is due primarily to the presence of certain structures during intrauterine life, which do not exist in the adult. The heart in the foetus is much larger in comparison to the body than in the adult, being at the second month about one-fiftieth of the entire bodily weight, at birth about one-one hundred and twentieth, and in adult life about one-one hundred and sixtieth. Also in the foetus at the fourth month it is found that the heart is in the vertical position, while it later assumes the oblique position.

The foramen ovale exists during foetal life as a small oval opening between the right and left ventricles. At about the fourth or fifth month there is a membrane developed from the posterior border of this opening which lies in the left auricular cavity and in developing advances across the opening, being attached only at the posterior border. It finally covers the entire lumen of the foramen ovale, and lying as it does in the left auricle, it acts as a valve, allowing the blood to progress from the right to the left auricle, but not in the opposite direction.

The eustacheon valve is a fold of fibrous tissue covered with endocardium, and while given the name of a valve, it in reality does not act as one. It is placed in front of the opening of the inferior vena cava in the right auricle and serves to guide the blood from this great vein into the foramen ovale and thus to the left auricle. It also serves the purpose of guiding the blood from the superior vena cava downward and through the auriculo-ventricular opening into the right ventricle. This fold in the adult is merely rudimentary.

The umbilical arteries or hypogastric arteries are two in number and exist only in the circulatory system of the foetus. They arise from the internal illiac arteries, and pass upward one on each side of the bladder and emit from the foetal body at the umbilicus. From here they proceed in the umbilical cord to the placenta where the blood which they carry becomes oxygenated. In the cord the umbilical arteries wrap themselves around the umbilical vein which is also a peculiarity of the foetal vascular system and the three vessels are surrounded by a fibrous covering which offers them ample protection.

The umbilical vein is single and progresses from the placenta to the umbilicus of the foetus in the umbilical cord, carrying the blood which has been oxygenated in the placenta. From the umbilicus the vein ascends in the foetus to the under surface of the liver where it gives off several branches. Several radicles are given off to the liver and enter the substance of this large gland singly, supplying its substance with blood. A large branch is given off to the portal vein and the blood which it carries enters the liver in company with the blood of the portal system. Still another branch is that which is a continuation of the umbilical vein, and it is known as the ductus venosus.

The ductus venosus is merely a continuation of the umbilical vein from the under surface of the liver to the inferior vena cava, and carries part of the blood from the placenta to this large vein, which transmits it directly to the heart.

The ductus arteriosus is a small artery about one-half an inch in length and one line in diameter. It serves to connect the pulmonary artery to the aorta, just after it has begun to descend and just after the left subclavian has been given off from it. Thus the blood which in the adult life passes to the lungs to be oxygenated, here enters the systemic system.

The placenta is a most important structure then in maintaining not only the oxygen in the blood, but also in supplying nutrition to the tissues of the foetus by means of the blood stream.

Keeping these structures in mind which we have described,

the circulation may be traced. Starting at the placenta the blood ascends through the umbilical vein to the under surface of the liver where it divides into three courses. One of these courses leads the blood directly into the substance of the liver, from whence it is carried away by the hepatic vein into the inferior vena cava; another joins with the portal vein and is thus carried through the liver from whence it is carried in the same manner to the inferior vena cava, and the third course (ductus venosus) leads directly into the inferior vena cava. Much of the blood then which comes from the placenta, laden with oxygen and nutritive material, passes directly into the substance of the liver, and it is for this reason that this organ is of such great size comparatively, in foetal life. All the blood thus far traced finally finds its way into the inferior vena cava, which is at the same time returning blood from the lower extremities, and with it the blood from the umbilical veins becomes mixed. The blood now ascends and enters the right auricle, but instead of proceeding from here through the auriculoventricular opening and into the right ventricle, as in the adult life, it is guided by the eustachian valve through the foramen ovale, and into the left auricle. From here it passes through the auriculoventricular opening into the left ventricle, and out as in adult life, past the semilunar valve and into the aorta.

From the aorta the blood is forced out principally through the three great vessels given off from the arch, namely, the innominate, the left common carotid and the left subclavian, all of which supply the head, neck and upper extremities. This area is drained by the superior vena cava, and the blood is then returned to the right auricle by means of this vessel. The blood from the superior vena cava is prevented from mixing to any appreciable degree with that from the inferior vena cava, by the eustachian valve, and so it passes downward and through the auriculoventricular opening into the right ventricle. From here it passes out by means of the pulmonary artery, but the lungs at this time in a state of collapse, are not being supplied with oxygen. The blood then instead of passing through these compressed capillaries

of the lungs, enters the ductus arteriosus and is carried by it to the aorta, just below the point of entrance of the left subclavian. It is this fact that accounts for the blood emitting from the left ventricle, being forced up into the three large arteries given off from the arch of the aorta. The stream of the ductus arteriosus tends to occlude the lumen of the aorta further down and the current is thus forced up and into these vessels. The same principal applies here as can be seen in a river flowing into another river. The current of the tributary entering the main stream, forces the current of the latter over to one side, and if there were means of exit here (as exists in the arch of the aorta) the water from the main stream would find exit largely in that manner.

The blood has now started its downward course through the aorta, and is given off to the various branches of this large vessel just as in the adult life. The aorta divides into the common illiac arteries and they into the external and internal illiac arteries. From the latter are given off branches known as the umbilical arteries which convey a part of the blood of the internal illiacs back to the placenta where it is again oxygenated and receives nutrition.

It can readily be seen that only a small portion of the blood of the vascular system of the foetus is thus oxygenated. Pure blood is carried to the under surface of the liver and much of it enters this organ. The pure blood which is carried to the inferior vena cava becomes mixed here with the blood which is being returned from the lower extremities and that which has gone through the liver also becomes mixed with it. The blood then, when it reaches the right auricle is largely venous. This blood is passed through the foramen ovale, left auricle, left ventricle, aorta and to the upper extremities, head and neck, where more of the oxygen is extracted. It is now forced out past the right auricle, right ventricle, pulmonary artery, ductus venosus and aorta to all parts of the trunk and lower extremities, and only a small proportion of it is returned to the placenta for oxygenation. It can be seen that the blood which supplies the head and

shoulders contains more oxygen and is richer in nutrition than that which supplies the other parts of the body (excepting the liver), and this accounts for the comparatively large size of these parts in the child at birth.

Changes in Foetal Vascular System at Birth

Taking up in order the peculiarities of the foetal vascular system, we will see what becomes of each one of them.

The foramen ovale becomes closed, by the fold which covered it, in the left auricular cavity, growing tight to its border, and finally forming a part of the interventricular wall. Sometimes there is a slight opening left between the two auricles by the fold not entirely covering the lumen, and when this is the case the venous blood in the right auricle mingles with the arterial blood of the left and so that which is expelled from the left ventricle is mixed, composed of both venous and arterial blood. This is the condition which exists in the so-called blue babies.

The eustachian valve atrophies and becomes a functionless fold of membrane lying in the right auricle.

The umbilical arteries remain from their point of origin to the apex of the bladder as arteries, and are called in adult life the superior vesical arteries. From the apex of the bladder to the umbilicus, however, the vessels become impervious and persist in the adult as fibrous cords supporting the bladder.

The umbilical vein becomes impervious in a very few days and exists in adult life as a fibrous cord known as the round ligament of the liver, extending from the umbilicus to the under surface of the liver. Both the umbilical arteries and the umbilical vein outside the body of the foetus, become impervious and dwindle, finally sluffing off from the body and leaving the depression of the umbilicus.

The ductus venosus becomes impervious in a very short time and it remains in adult life as the venous ligament of the liver.

The ductus arteriosus also becomes a fibrous cord, and serves to hold the pulmonary artery and the aorta in their normal posi-

tions. While the lumen of the ductus arteriosus is not decreased immediately upon delivery, the child begins to breathe, and this expands the capillaries of the pulmonary region, so that the resistance offered by this route is less than that offered by the aorta.

SECTION V

CHAPTER XXX

THE LYMPHATIC SYSTEM

The lymphatic system is composed of the lymphatic vessels which convey lymph from practically every part of the body, and lymph nodes which are found along the course of the lymphatic vessels and serve to supply lymphocytes to the lymph carried in the lymphatic vessels. The lymph found in the vessels and nodes (glands) may also be considered as a part of the lymphatic system.

It was formerly supposed that the lymphatic vessels began as dilated spaces in the tissue, which spaces were drained by minute terminal lymphatic vessels. This, however, upon further investigation was found to be erroneous. It is true that many of the terminal lymphatic vessels have their origin in these spaces, but instead of draining them like small canals coming from a lake, it is known that they project into the spaces small closed extremities, and that the lymph which finds its way into the lymphatic vessels is produced by Innate Intelligence expressing herself in the cellular activity exercised through the cells of these blind lymphatic capillaries.

A clear distinction must be drawn here between the serous fluids and the lymph.

Lymph is the name given to that fluid of the body which is found within the lymphatic vessels, and it must be remembered that it consists very largely of serum.

Blood is the name given to that portion of the fluid of the body which is found within the vascular system, and it also consists very largely of serum.

The term serum is applied to that part of the fluid of the body, which is neither in the vascular nor lymphatic vessels, but is in an independent circulation by itself, separate and distinct from all other systems. There are spaces in the body which are classified as perivascular, perineural, and intercellular. These are true serous spaces and their fluid is of the serous character. It is derived from the osmosis of the serum contained in the blood through the capillary walls, and after serving its function as serum in the serous space, Innate exerts a selective influence through the lymphatic walls, and much of the serous fluid is taken into the lymphatic vessel to aid in the formation of lymph.

Lymph glands of nodes we have considered in the study of the ductless glands, and it will suffice to say here that they vary in size to a marked degree, from microscopical size to that of a small olive. They are distributed over the entire body, along the course of the lymphatic vessels with the exception of those below the knee and below the elbow. Here, although lymphatic vessels exist, the nodes are absent. No lymphatic glands are found in the brain, spinal cord, eyeball, or the internal ear.

Lymphatic vessels may be divided into two classes, the superficial and the deep. These two sets, divided as are the veins of the body, follow in a general way the veins in their course, and it is found that they communicate by lymphatics known as communicating ducts. The lymphatic capillaries originate as has been stated, from the perivascular spaces, the perineural spaces and the intercellular spaces, existing here as closed extremities, into which the lymph must find its way from the surrounding tissues. However, there are found minute tubules in the intestinal wall having their beginning in blind extremities within the villi. These vessels from their connection and their structure are classed with the lymphatic vessels, although they are given the special name of lacteals. This is because they convey a milky fluid known as chyle from the intestine to the beginning of the thoracic duct, which is a lymphatic duct and receives the majority of the small lymphatic vessels of the body. The lymph, then, which finally

finds its way into the vascular system, is derived from the tissue spaces and also from the villi of the small intestines.

The thoracic duct is the largest duct of the lymphatic system. It is from fifteen to eighteen inches in length, extending from the lower border of the second lumbar vertebra in the abdominal cavity, toward the superior and terminating in the venous system at the point of junction of the left subclavian and the left internal jugular veins. At its lower border the thoracic duct is dilated and this dilatation is known as the receptaculum chyli, because most of the lacteal vessels empty here. The thoracic duct receives in its course the lymphatic vessels which drain the entire trunk below the diaphragm and the lower extremities. It also receives those which drain the left side of the body above the diaphragm.

The right lymphatic duct is much smaller than the thoracic duct and drains a smaller portion of the body. About half an inch in length it empties into the venous system at the junction of the right subclavian and the right internal jugular veins, being made up of vessels which drain the right side of the thorax, neck, head and right arm.

The lymphatic vessels are made up of a wall which is divided into three coats, the outer, middle and inner. The outer coat is composed of fibrous tissues intermingled with some smooth muscular fibers arranged in a longitudinal or oblique direction. The middle coat is formed of smooth, muscular fibers, arranged in a longitudinal direction and having interspersed in its structure some elastic fibers. The inner coat consists of two layers. The outer is of elastic fibers and serves as a basement membrane upon which are placed the endothelial cells, arranged edge to edge, and flattened in shape. The lymphatic vessels, as the veins, have a large number of valves, and here the structure is the same. Two cusps are present, forming the little pockets in the wall and all pointed in one direction so that the lymph is able to pass only in the one direction, toward the two points of emission in the large veins of the neck.

The newer idea that the lymphatic system is a closed one has

entailed a radical change in the consideration of the lymph. Formerly it was supposed that the lymph was a part of the blood (was in fact blood plasma) which had found its way outside the vascular system, and was carried from this point of emission to the point where it again entered the vascular system. In brief, lymph was a fluid (blood plasma) which left the capillaries and finally returned to the great veins as plasma. There was thought to be no difference in lymph at different points of the lymphatic system nor in different parts of the body. Now certain proofs have been brought forward that show the lymph in different parts of the body is of different consistency, and further that the lymph in the tissue spaces around the vascular capillaries is not merely an exudation of blood plasma through the capillary wall, but is a definite fluid, of different composition under varying conditions.

In order to establish a line of distinction between the fluid which Innate takes from the vascular system and passes into the surrounding spaces and that which passes from the tissue space through the lymphatic wall and into the lymphatic vessels, we will call the former tissue fluid, and the latter, lymph.

Early investigators assumed that the cause for the fluid making its exit from the capillaries into the surrounding spaces was merely one involving the difference in pressure and concentration. This contention would put the matter purely upon a physical basis, and in fact was founded upon the supposition that if the intracapillary pressure was raised, there was an increased flow of fluid through the capillary walls.

This theory was severely questioned when it was discovered that certain substances, when injected into the blood, caused a marked increase in the rate of flow of lymph, without appreciably affecting the blood pressure. This contention was first held by Heidenhain, who called these substances lymphogogues and divided them into two groups. One group not only increased the formation of tissue fluid, but increased the specific gravity of the blood, while the other class increased the tissue fluid and decreased the specific gravity.

The truth of the matter is that the cells of the walls forming the vascular capillaries is under the control of Innate Intelligence just the same as those of any gland in the body. In the glandular structures we know that Innate exercises a selected influence over the substances which come in contact with these cells. taking from them those materials which are useful in the manufacture of that particular gland. In the cells of the capillaries we have the same selective influence of Innate, and here she takes from the blood, which is continually in contact with the cells, those materials which will be of value in the surrounding tissues, passes them through the capillary wall and thus makes them accessible to the cells which need them. If we assume that each cell in every capillary in the body exerts an individual selective influence, we assume the standpoint that the action is a localized one and is performed for the benefit of that particular cell. This can never be the viewpoint in the study of any cell, organ or system in the human body. Always there is the great controlling influence of the Innate Intelligence exercised through the nervous system to which we must revert. This then is one of the actions of the body, which the physiologists who would explain every action by the laws of chemistry and physics, have been unable to solve with those laws as a basis, and have fallen back on the explanation that the cells exert a selective influence. This is true as far as it goes, but we must also recognize the fact that there is something else which in turn controls this selective influence. The great nervous system which acquaints the Innate Intelligence with the various conditions existent in the body, serves to convey the impulses of secretion to the cells of the vascular capillaries, producing in them the activity which is needed, and as a result of this control we have the selective activity of the cells expressed. These efferent which control the cellular action in the walls of the capillaries are in turn the result of afferent impressions sent to the brain, where they are interpreted by Innate Intelligence, and thus the necessity for secretory impulses is made known.

In the active organs such as glands, where there are certain substances taken from the blood which are necessary in forming the peculiar secretions of these glands, the secretory activity of the vascular capillaries seems to be controlled in about the same proportion as are the secretory cells of the gland itself. First, it must be understood that while the glandular cells take indirectly from the serum in blood, the materials which are needed in forming their secretion, these substances come directly from the serous fluids into the cells. In brief, part of the fluid of the blood passes out through the vascular capillaries, not directly into the secreting cells of the gland in which they lie, but rather into the tissue space which contains serous fluid. From this tissue space there are two methods of emission, one into the glandular cells which alter the substance taken in to form their peculiar secretion, the other through the lymphatic wall and into the lymphatic system. Experiment has shown that when a gland is active and must receive more materials from the serous fluids, the selective influence of Innate, exercised through the capillary cells is more active, and thus while the serous fluids are being depleted by the glandular cells they are being replenished by Innate through the capillary cells from the blood. The lymphatic vessels draining this area are found to be approximately normal in the quantity of fluid which they carry, proving that the two sets of secretory cells, vascular and glandular, function at about the same rate. In general we may say that while Innate supplies, through the vascular system, the liquid tissue of the body with the proper quantity and quality of materials, the lymphatic system, under the control of this same Innate, is concerned in maintaining this tissue at the proper quantity and quality, taking from it the elements which are needed in lymph and leaving that which is to be used by the tissue cell. The lymphatic system may be looked upon as a complicated balance which Innate utilizes in regulating the vascular system, that it may be kept at a certain degree of pressure, and also that those nutritive materials which

are contained in its serum may be passed into the serum of the blood stream and distributed rapidly by this means to all parts of the body.

The general principals which control the passage of fluids from the blood stream into the surrounding tissue spaces, will control the passage from the tissue spaces into the lymphatic vessels. Here we may not base our conclusions upon the purely mechanical and chemical laws, but must state that Innate Intelligence, through the cells found at the capillary terminations of the lymphatic vessels, exerts the same selective influence upon the fluid tissue as is exerted by it, through the cells of the vascular capillaries upon the blood passing through them. We must not lose sight of the fact that these cells are live cells; that they are controlled by the Innate Intelligence the same as the cells of other parts of the body, and that under the control of this influence they function normally. If perhaps the tissue cell is cut off from the proper nerve supply by a subluxation in the spine, the chemical laws are still there, the physical laws are still present, and still we have incoordination. If the cells acted purely in response to the chemical and physical factors, the nervous system through which Innate transmits impulses and receives impressions would be necessary.

CAUSES OF THE LYMPH FLOW

There are several considerations concerned in the onward propulsion of lymph in the lymphatic system. The peristaltic activity in the intestine undoubtedly assists in this onward movement by compressing the blind extremities of the lacteals, thus squeezing the chyle out from them and onward toward the receptaculum chyli. Remembering that the lacteals as well as the other lymphatic vessels are supplied with valves, we know that this chyle cannot return, and as a result there is a suction influence exerted by the lacteals upon the material contained in the cells of the villi. The casual observer would pursue this causative factor no further than to say that the chyle is propelled

by the suction influence of the lacteal vessels, and that the entire action rests upon the purely mechanical feature of a fluid flowing from a high to a low pressure. Why, then, does the propulsion not occur in the dead body? It is because the condition of a high and low pressure at different parts of the lacteal vessel is merely the effect of the expression of motor impulses, which are sent by Innate Intelligence to the muscular walls of the intestines, producing here the peristalsis. Innate expresses herself also in producing all muscular contractions over the entire body. Thus she will produce a contraction of the biceps which will upon shortening, press the lymphatic vessels and occlude their lumens. This will force the lymph out, and as the valves are so arranged that it can only pass toward the thoracic duct or the right lymphatic duct, these are the points toward which it is forced. Here again we have the physical laws expressed but always there must first be the mental impulse sent out by Innate to produce those conditions which are productive of the expression of these laws. The other vital feature which is concerned in the propulsion of lymph is the fact that it emits from the vascular system at a point where the pressure is less than at the point where it enters. Following here the physical law of fluids passing from a high to a low pressure the lymph must pass in the same direction as the blood in the vascular system. This physical condition is brought about by the contraction of the heart, and this, in turn, reverts again to the mental impulses which are expressed in this manner.

SECTION VI

RESPIRATORY SYSTEM

CHAPTER XXXI

THE RESPIRATORY STRUCTURES

The respiratory system consists of the lungs and all the air passages leading to them. If taken in the full meaning of the term, the respiratory system would include every part of the body which is directly interested in the inhalation and consumption of any part of air. This broad meaning, however, would include all the tissues of the body, as every cell must have its quota of oxygen, and be able to throw off its products of katabolism. We will then consider the respiratory system in the restricted sense.

The Trachea

The trachea or windpipe, is a muco-musculo-cartilaginous tube which begins at the lower border of the larnyx, being continuous with it, and terminates in a right and left bronchus. Its upper border is about opposite the body of the sixth cervical vertebra, while its lower border extends to a point about opposite the body of the fourth dorsal vertebra. It is about four and one-half inches in length, and at its widest point, at the center of its extent, it is from ¾ of an inch to one inch in diameter.

The Bronchi

The bronchi are two in number, a right and a left. The right bronchus is shorter, (about one inch long) more perpendicular and of greater diameter than the left. The left is longer (about two inches long), more horizontal and smaller in diameter.

The right bronchus enters the hilus of the right lung opposite the body of the fifth dorsal vertebra, while the left enters the hilus of its lung about opposite the body of the sixth dorsal vertebra. The right bronchus gives off a large branch which supplies the upper lobe of the right lung, and then proceeds downward, and at its point of bifurcation, one of the branches is sent to the middle and one to the inferior lobe. The left bronchus divides into the main sets for the supply of the left lung, one set passing to the upper lobe and one to the lower lobe. Besides the main branches given off from the bronchi there are small and comparatively unimportant ones, but whether large or small they all branch off into smaller divisions, and these divisions are known as respiratory bronchioles. The respiratory bronchioles are further divideed into alveolar ducts, or terminal bronchioles, which form the only means of entrance and exit to and from the lobule. Each alveolar duct terminates in several cavities of irregular form which are known as atria, and from each atrium are given off infundibuli, or air sacs. An infundibulum is a small cavity resembling a bunch of grapes, the stem of which corresponds to the intercellular passage and originates at the atria. Each individual grape corresponds to the pulmonary alveolus, which is the very smallest division of the lung, the lung unit.

Histology of Trachea and Bronchi

The trachea and bronchi consist of an outer layer of thin fibrous tissue, and just within it another layer of like structure. Between these two are arranged the cartilaginous rings which serve to hold open the trachea, and thus offer no obstruction to the passage of air. These cartilaginous rings are of the yellow elastic fibro-cartilage, and admit of some degree of variation in their shape. They are about sixteen to twenty in number, incomplete at their posterior borders, thus covering only the sides and anterior walls of the trachea. The lower border of one does not rest upon the upper border of the cartilage next below it, but

between the two there is a small interval. In this interval the fibrous membrane which covers the outer surface of the rings unites with the membrane which covers the inner surface of the ring, and the two form a single thick membrane. This same condition occurs at the posterior where the rings are incomplete and do not cover the entire wall. Here, too, the two membranes unite to form the one thick membrane. Because of the fact that the rings are not complete but leave a space at the posterior, the anterior and lateral walls are convex, but the posterior wall is flattened. Sometimes these cartilaginous rings are joined one with another and sometimes they are forked at the ends. There are about eight of the rings in the right bronchus and twelve in the left bronchus, being imbedded in the same way, but leaving a wider space at the posterior.

The muscular coat is found just within the fibrous coat described and consists of two layers. The outer is comparatively unimportant and is composed of longitudinal fibres, while the inner is composed of transverse fibers and forms the main bulk of the muscular coat. These fibers are of the involuntary type.

The mucous membrane is found within the muscular coat forming the lining of the entire lumen. It consists of several layers. The main bulk is formed by a combination of areolar and lymphoid tissue, and on the inner border of this tissue we have a great quantity of fibers forming a basement membrane, upon which rest the columnar cilliated epithelial cells. Interspersed in these columnar cells we have great quantities of goblet cells, and this gives rise to the formation of large quantities of mucus by this membrane. This is necessary, because the air continually passing over the wall tends to dry up the secretion rapidly, and the secretion of mucus is absolutely essential in order to act as a protection against the influx of foreign materials into the lungs.

In the mucous membrane of the bronchi and the smaller bronchial tubes, however, is a feature which does not exist in the

trachea; namely, a layer of circular muscle fibers, which is called the muscularis mucosa. It is this layer which by its contraction tends to decrease the lumen of the tubes in asthma, and this fact, together with the increased secretion of mucus is responsible for the marked dyspnoea present in this disease. There are many small glands of the racemose type found at the posterior of the trachea, called tracheal glands. These are lined with columnar epithelial tissue, and secrete mucus, which is passed into the lumen of the trachea. Mucus is thus manufactured at a rapid rate, and is continually being forced from the small bronchial tubes to the larger ones, until finally it arrives at the larynx, where it produces a vibration causing an impression to be carried to the brain. Here an interpretation is made and Innate becomes aware of the fact that there is a foreign material to be expelled. A cough is the result, and the dust laden mucus is expelled to the external.

As the bronchial tubes divide and subdivide, becoming smaller and smaller, the structure of their wall undergoes some change. The coats become thinner and thinner, the cartilaginous element less and less noticeable, until when the diameter of about one-fortieth of an inch is reached, the cartilage is present only in very small flakes, and in vessels slightly smaller is absent altogether. The fibrous tissue becomes thinner, and the muscular coat, although thicker in comparison to the size of the tube, is only a thin coat. The mucous membrane becomes thinner with only a thin basement membrane, and resting upon it are cells of the ciliated variety, but instead of being columnar in shape they are cubical.

The Pulmonary Alveoli

We have stated that each infundibulum is made up of a central passage known as the intercellular passage, and that grouped about this space are openings, resembling the arrangement of grapes on a stem. Each of these little sacs is known as an alveolus. The wall of the alveolus is formed of a fine

thin membrane lined by epithelial tissue, but in this location of the pavement variety. About one-fiftieth to one-seventieth of an inch in diameter, the alveoli are of different shapes, dependent upon the shape of the alveoli around them. Just as a bunch of grapes, squeezed into a basket, when removed shows some grapes flattened on one side, so in the alveoli the shapes are altered. This thin walled alveolus offers the only membrane presenting itself between the blood of the pulmonary system and the air which is taken into the lungs when breathing takes place, with the exception of the wall of the capillary itself.

The lungs are placed in the thoracic cavity at the sides and in front of the heart and great vessels. The space at the center of the thoracic cavity is known as the mediastinum, and in it are placed the thoracic duct, the oesophagus, the heart, pericardium great vessels, thymus gland and many other less important structures, as well as lymphatics and nerves. On the right side of these organs we find the right lung and on the left the left lung, and they extend from the diaphragm below to the shoulder girdle and muscles above. The right lung is divided into three lobes, a superior, middle and inferior, while the left lung is divided into two lobes, the superior and inferior. These lobes are further subdivided into lobules, those on the surface being large and those on the interior being small. The lobules on the surface are pyramidal and those in the internal structure are of various shapes. There is just one single means of communication, which the external world has with the lobule, and that is through the ramification of the terminal bronchiole which supplies it.

Pleura

The pleura is a sac completely surrounding the lungs, and separating their walls from the walls of the thorax. There is in reality one sac around each lung, and their spaces do not communicate, thus giving rise to the advantage that if one side is injured the other side is not necessarily affected. We speak of

the pleura as a closed double walled sac, because it does consist of two layers, and these are reflected one upon the other so that they are continuous. The outer wall of the pleura is the one which is adherent to the wall of the thorax, the diaphragm, and the viscera found in the mediastinal space. The inner wall is closely attached to the surface of the lungs. The former is the parietal layer and the latter is the visceral layer. Between these two is a space filled with a serous fluid which serves to lubricate the outer surface of the visceral and the inner surface of the parietal layers, so that in the act of respiration the one may glide easily over the other. We call this cavity where the fluid is contained the space of the pleura, but in reality during life, when the lungs are in healthy condition and neither of the pleural walls are punctured, the two layers adhere closely to one another, and the space is occupied by the fluid contained. The wall of the pleura is formed of connective tissue, which is united to the substance of the lung by a subserous connective tissue continuous with the areolar tissue of the lung. Both the parietal and visceral layers of the pleura are lined with endothelial tissue, and both these layers have in the connective tissue forming them quantities of elastic fibers.

Area for Oxygenation

In our study of the structure of the lungs we have noted that the arrangement was very complicated. This great area is present for the purpose of providing the greatest possible surface where the carbon dioxide in the blood is exchanged for the oxygen in the air. Various computations have been made as to the extent of this area, and it must be admitted that the accuracy of the following figures cannot be vouched for. However, it is a general approximation and serves to convey something of the complicated structure of the lung. The size is about that of a floor 30 feet wide by 36 feet long, or 1,080 square feet.

Blood Supply of Lungs

The lungs are supplied by two sets of vessels which convey to them blood of two different kinds. The pulmonary arteries convey venous blood from the right heart to be oxygenated, and returned from thence to the left heart, from where it may be distributed to all parts of the body. The bronchial arteries convey blood to the lungs to supply the lung tissue with oxygen. This is necessary, because even though the oxygen is able to pass through the thin walled pulmonary alveolus, it cannot as readily reach the supporting framework of the lungs and the air passages, and these would be unable to function for want of oxygen if they should have to depend upon the pulmonary circulation.

CHAPTER XXXII

RESPIRATION

Inspiration is the act of taking air into the lungs, and expiration is the act of expelling it from the lungs. The combination of these two acts is called respiration. In our description of the lungs, however, it will be remembered that no muscles were described which might in any way have an effect on the lungs in making them expand or contract. The following question then presents itself: What muscles are utilized in inspiration? Here we come to the important physiological function of the pleura. This double sac, one layer of which adhers to the thoracic wall, diaphragm and mediastinal viscera, while the other adhers to the lung tissue, serves as a binding link between the lungs and these surrounding structures, because, the apparent space between its two layers is merely a vacuum. Now as the outer layer changes its position the inner must follow its change and glides easily over it. Remembering the structures to which the outer layer is attached we can readily see where the muscular effort must come from. During inspiration, the diaphragm contracts, and by its contraction assumes a lower position in the trunk, increasing the size of the thorax and forcing out the wall of the abdomen. The ribs also are raised and thus aid in increasing the thoracic cavity.

If the cavity of the thorax is increased, the walls of the lungs must follow because of their connection by the pleura, and as soon as this occurs the space in the lungs must be filled with something, therefore, the air rushes in from the outside and inspiration is thus produced.

To illustrate we may assume that we have an ordinary metal cylinder of 2 quarts capacity in the middle of which is the

head of a sliding piston making the capacity above it 1 quart. Now if a thin rubber cap is placed over the top of the cylinder, and a suction pump begins to draw the air out of the tube, the rubber cap begins to show a concave surface, because it is being pressed down. Assume now that the rubber cap is distensible enough to be drawn so far into the cylinder that it follows the contour of it and adhers to its walls and bottom. Now if the piston forming the bottom is drawn downward the cavity of the cylinder is made larger and instead of the capacity being 1 quart it is changed to 3 pints. Because of the vacuum existing between the walls of the cylinder and the rubber, the latter must follow the contour in its changed position. When it does this the one quart of air which it formerly contained is forced to fill a space of three pints, and therefore the pressure must be lowered. Air always flowing from a high to a low pressure, it equalizes itself by entering the cylinder through the opening at the top from the external world. This comparison is only valuable in that it states the changes which occur in inspiration from a purely mechanical standpoint; the cylinder representing the thoracic wall which is capable of changing its shape and capacity, and the rubber membrane representing the lungs which follow this changed position.

Thus far we have shown what change occurs in the thorax, but have not explained why it occurs. The enlargement of the thorax during inspiration is purely a muscular effort, and it is found that the cavity increases in its vertical, in its antero-posterior and in its lateral diameters. The vertical diameter is increased by the contraction of the diaphragm which is the dome shaped muscle dividing the abdominal from the thoracic cavity, and having at its center a slight depression for the attachment of the central tendon and extending from here downward to its attachment to the walls of the trunk. When the diaphragm contracts the central tendon is drawn downward, and the entire muscle is lowered, thus increasing the vertical diameter. The lateral and

antero-posterior diameters are increased by the raising of the ribs upward and outward. It should be borne in mind that the ribs are placed obliquely, having their attachment at the spine and extending from here to the costal cartilages by a curved course, which carries the anterior extremities downward. The spine then forms the base upon which the ribs are raised, and when this movement takes place the sterum is forced forward and the lateral walls of the thorax outward. The increase in the antero-posterior and the lateral diameters is produced by the contraction of the external intercostals (muscles extending from the lower borders of the ribs to the upper border of the ribs below, with the fibers extending downward and forward), internal intercostals (muscles extending from the ridge on the inner surface of the rib to the upper border of the rib below, with the fibers extending downward and backward), levatores costarum (muscles extending from the apices of the transverse processes of the seventh cervical and eleven upper dorsal vertebrae to be inserted into the first and second ribs between the angle and the head), and the scaleni (three muscles, anterior, posterior and middle, which arise from the transverse processes of the cervical vertebrae below the atlas, and are inserted into the two upper ribs). These muscles, however, are those used in ordinary easy respiration. When the breathing becomes forced the powerful muscles of the trunk also come into play. These are:

Trapezius (arises from the external occipital protuberance, ligamentum nuchae, spinous processes of all cervical and dorsal vertebrae, and extends to its insertion in the inner border of the outer extremity of the clavicle, and the acromian process and part of the spine of the scapula).

Serratus posticus superior (arises from the ligamentum nuchae and the spinous processes of the upper dorsal and lower cervical vertebrae, and is inserted into the upper border of the second, third, fourth and fifth ribs, not far outside the angles).

Pectoralis minor (extends from the coracoid process of the

scapula to the outer surface of the third, fourth and fifth ribs near their terminations in the costal cartilages).

Sterno-cleido-mastoid (extending from the upper extremity of the sternum and the inner extremity of the clavicle to the mastoid process of the temporal bone).

It can readily be seen that these muscles all tend to raise the ribs, and by so doing they increase the capacity of the chest.

Expiration is the term applied to that action wherein the air leaves the thoracic cavity and proceeds to the external. This, as in inspiration, is accomplished by decreasing the size of the thoracic cavity, and is not a muscular action of the lungs themselves. However, in the case of expiration we have a different circumstance to confront. During inspiration the lungs are being stretched further and further, and thus the kinetic energy expended by increasing their distension is stored up in their walls as potential energy. Immediately when the muscles of inspiration are relaxed this potential energy begins to assert itself, and changes into kinetic energy expressed by the expelled air. During expiration then there is no necessity for muscular contraction of any of the muscles of the thorax, and the air is expelled merely as the result of the elasticity of the lungs tending to make them recoil to their former position. The lungs are ably assisted in this action by the thoracic wall itself, which, because of the great quantities of cartilage contained, is also elastic and tends to return to its former position after the inspiration has been produced. In the foregoing we have spoken of the natural quiet respiration which accompanies no physical exertion. In the event that the individual has been or is under some physical or mental strain, the breathing may be more rapid, thus constituting forced expiration. When this occurs the external and internal intercostals are brought into play, the serratus posticus inferior (extending from the spinous processes of the lower two dorsal and upper three lumbar vertebrae to the four lower ribs just outside their angles), which holds the lower ribs down is also used, and every muscle

of the abdomen which may compress the abdominal viscera and thus force the diaphragm up more rapidly, is brought into play.

Types of Respiration

It is found upon observation that there are three distinct types of respiration, and they may be illustrated in the child, the man and the woman. In children the diaphragm is used more than any other set of inspiratory muscles, and as a result the abdomen is forced outward at each inspiration. This is known as the abdominal type of respiration. In men the diaphragm is used together with the muscles of the ribs, thus forcing the abdomen out to some degree, and also raising the ribs. This is known as the inferior costal type. In woman the ribs are raised practically to the exclusion of any important action of the diaphragm, and this produces the superior costal type. It is said that this type is developed, due to the use of corsets, which will not allow for a distension of the abdomen to any great degree.

Stethograph

The stethograph is an instrument used for recording the respiratory action and is nothing more than a rubber bag bound to the chest wall, so that expansion of the chest compresses the air in it while contraction of the chest wall serves to release the tension. Connected to this rubber bag by a tube is a recording drum and the record made simply shows an increase and a decrease in the size of the thoracic cavity. Along the course of the tracing are secondary curves, due to the action of the heart. This record shows that there is very little difference in the time of inspiration and that of expiration, although usually the latter is slightly longer. We also learn from the record that there is a slight pause between each respiratory effort, from the termination of expiratory action until the beginning of the next inspiratory effort. The respiratory murmur is the sound which is heard in placing the ear or a stethescope over the region of the larynx or

bronchial tubes and is due to the vibrations of the air column in passing through the larger air passages.

Quantity of Air Breathed

Various terms have been applied to the different amounts of air that are breathed during respiration and various estimates have been made as to their quantities. Here, however, those quantities will be given which seem to be near the average computation.

Tidal air is the amount of air which is taken into the lungs at each inspiratory effort and expelled from the lungs at each expiratory effort. It is in amount about 30 cubic inches, and this computation is made considering the subject to be in an easy position and breathing easily. Of course any muscular effort tends to raise the quantity of air breathed as well as increasing the number of respirations in a given time. It is estimated that the air passages themselves have a capacity of 10 cubic inches, and they must of necessity be filled before the air can reach the pulmonary alveoli, where the exchange of oxygen for carbon dioxide takes place. However, the air passages at the time inspiration begins are filled with air, as they are non-collapsible, owing to the cartilage contained in their walls. The column of air then which is inhaled becomes mixed with the air in the bronchial tubes; first, with that in the larnyx and trachea, and at this time it becomes less pure than when it was on the external. This air in the trachea then becomes mixed with that in the larger bronchial tubes, where it becomes even less pure, and this then with the air in the small bronchial tubes, where it becomes more impure than ever. When it is considered that this air in the small bronchial tubes is then mixed with that in the pulmonary alveoli, which is in amount about 190 cubic inches, some idea may be gained of the difference in the purity of the air on the external and that with which the blood makes its interchange in pulmonary alveoli. This comparatively impure air, however, contains all the oxygen necessary to supply the blood when the

body is at rest, and this oxygen passes through the wall of the alveoli and that of the pulmonary capillaries into the blood. In exchange for the oxygen the blood gives up to the pulmonary air quantities of carbon dioxide, and by the time this exchange has taken place the air in the alveoli is so impure that it no longer can be used and the process of expiration begins. During the process of expiration the air (only a small part of the air in the alveoli is really expelled) in the alveoli is started on its passage to the external, and first becomes mixed with the more pure air of the small bronchial tubes. (It should be remembered that the air in the air passages has not been deprived of any of its oxygen.) This is in turn mixed with that of the bronchial tubes and this with the air of the trachea, becoming purer all the time because it is continually mixing with air which during the process of inspiration was left in a purer state.

Complemental air is the term applied to that amount of air which may be inspired, by the most violent inspiratory effort, after the normal inspiration has taken place. In quantity it is about 100 cubic inches.

Supplemental air is that air which may be expelled by the most violent expiratory efforts, after the tidal air of normal respiration has been expelled. It is in quantity about 100 cubic inches.

Residual air is the air which by the most violent expiratory efforts cannot be expelled from the lungs. This is because of the lungs being always on the stretch, and even when the thorax, by violent muscular exertion, decreases its size to the minimum, they are still stretched to some degree and contain some air. The residual air is in quantity about 100 cubic inches. The only way in which all the air of the lungs may be expelled is by the puncturing of one of the layers of the thorax. In this event the loss of the vacuum between the layers of the pleura prevents the thoracic wall from maintaining its grip on the lung, as it were, and so it is allowed to recoil as far as its elasticity is able to draw

it. This squeezes the air out of the lungs, but it should be remembered that the space must be filled with something, so it is filled with air between the two layers of the pleura. This condition when existing in one lung is known as pneumothorax, and is not fatal because of the inability of only one lung to function, but should it occur in both lungs (double pneumothorax) respiration would be impossible and death would occur.

The respiratory capacity is the expression used to indicate the amount of air that may be taken into and expelled from the lungs by using the greatest possible inspiratory force and the greatest possible expiratory force. It can readily be seen that this action will include the complemental, the tidal and the supplemental air. But even after this expiratory effort has been made there is still the residual air contained in the lungs, for it can never be expelled; therefore the respiratory capacity and the lung capacity varies by the amount of the residual air. The respiratory capacity is about 230 cubic inches, while the total lung capacity is the respiratory capacity plus the residual air, or 330 cubic inches. It should be borne in mind that these figures may vary somewhat, just as the size of the individual may vary, but they serve to give a fair idea of the average quantities of air breathed.

Number of Respirations Per Minute

The rapidity with which breathing takes place varies somewhat, dependent upon age, exercise, health, etc., but, as a rule, the respirations take place at the rate of about 14 to 18 per minute. The number of respirations increase during exercise, and, as a rule, in proportion to the number of heart beats, although this is not always the case.

Inspiratory and Expiratory Force

It is possible to produce a more forcible expiration than inspiration, possibly because of the greater strength of the expiratory muscles, but this factor is largely aided by the natural

elasticity of the lung tissue. During inspiration the muscles must overcome the natural tendency of the lungs to collapse, and so the most of their force is used in this way and less is left to act upon the manometer used to measure the force. In expiration, on the other hand, the elasticity of the lungs is a factor in aiding the muscles of forced expiration; further than this the muscles of expiration are used in the special respiratory acts such as coughing, sneezing, singing, speaking, etc., and so develop considerable strength.

Function of the Muscular Fibers of the Bronchial Tubes

Throughout practically all the bronchial tubes we have a layer of muscular fibers, and the question has often been discussed as to whether these have anything to do with the respiratory effort. This is hardly probable, and it is more likely that they are used to control the size of the lumen through which the air enters the lungs, to control the amount of air entering each section, and regulate it favorably with the blood supply to that particular section.

CHAPTER XXXIII

CHEMICAL CONSIDERATIONS

Solution of Gases in Liquids

The study of the interchange in the lungs of carbon dioxide for oxygen involves certain phases of chemistry which must be studied and considered before a thorough understanding can be held as regards the subject.

Owing to the fact that blood is a complicated substance, we shall consider first the relation that certain gases bear to water. If, for instance, a given quantity of water be shaken up in a vessel containing oxygen a certain amount of the oxygen is taken into the solution. The amount depends upon the pressure at which the oxygen is held, the temperature of the solvent and upon the solubility of oxygen (that is the amount of oxygen which may be taken up under constant conditions). Some gases are very easily taken up while others are not.

As an example, let us assume that, at the atmospheric pressure a large bottle contains oxygen, into which is introduced one c. c. of water. Experiment has shown that the water takes up 4/100 c. c. of oxygen. If at the same time one c. c. of water is introduced into a like bottle containing nitrogen it will take up 2/100 c. c. of nitrogen. The degree to which certain gases are absorbed in one c. c. of water at the atmospheric pressure, is known as the coefficient of that particular gas. Therefore, the coefficient of oxygen is .04 while the coefficient of nitrogen is .02. The coefficient of a gas is then determined by the quantity of that gas which may be dissolved at the atmospheric pressure. The quantity varies directly with the atmospheric pressure; therefore, if .02 c. c. of nitrogen are dissolved at normal pressure, the

amount which will be dissolved at 4/5 the normal pressure will be 4/5 of .02 or .016 c. c. Again, if the quantity of oxygen absorbed in one c. c. of water at the atmospheric pressure is .04 c. c. then the amount which will be dissolved at 1/5, the normal pressure is 1/5 of .04 c. c. or .008 c. c. When a gas forms a combination with other gases it exerts the same pressure as if it existed alone, filling the entire space, while the other gases are absent. Keeping this in mind we will assume that a c. c. of water is shaken with air (4/5 nitrogen and 1/5 oxygen). If the nitrogen existed alone it would produce a pressure of 4/5 the atmospheric pressure, and .016 c. c. would be absorbed. If the oxygen is taken it would produce a pressure of 1/5 the atmospheric pressure and .008 c.c. would be absorbed.

Tension

When the point is reached in absorption of a gas in a fluid where the maximum amount of gas has been taken up (in the case of nitrogen in water 2 per cent is dissolved) the gas on the outside, and that in the fluid are in a state of equilibrium, because the pressure in the one is exactly the same as the pressure in the other. The term tension is used to indicate the pressure of the gas in the solution. The pressure then is the same as the tension. If the quantity of the gas held in solution varies in proportion with the pressure, then it also varies in proportion with the tension. Taking again the case of oxygen, which at 1/5 the atmospheric pressure contains .008 c. c., the tension would also be 1/5 the normal, and the quantity of oxygen held in solution would be .008 c. c.

To make use of the foregoing data to compute the tension of a gas, say carbonic acid in blood, assume that we have four reçeptacles containing gases. The first bottle has .06, the second .055, the third .05, and the fourth .045 of carbonic acid mixed with other gases at the atmospheric pressure. Now a certain amount of blood direct from the vascular system is forced into each bottle, and after thorough shaking the gas of each bottle

is drawn out and analyzed by an air analysis apparatus. It is found that in the first, which contained .06, only .057 of carbonic acid is found. In the second, which did contain .055, only .054 is present. In the third, which did contain .05, .051 is found, and in the fourth, which did contain .045, .047 is found. This shows that the gases of the first and second bottles gave off carbonic acid having a pressure of .06 and .055 respectively, and therefore that the pressure or tension of carbonic acid in the blood is less than either of them, while in the third and fourth, where the bottles contained .05 and .045 respectively, that this amount was increased; therefore, the pressure or tension of the carbonic acid in the blood was in excess of either of these specimens. We are, therefore, led to the conclusion that the tension of the carbonic acid in this blood is between .05 and .055 of an atmosphere.

Amount of Gas in Blood

Different instruments have been devised for the purpose of measuring the amount of certain gases in blood, but it is not necessary at this time to enter into a discussion of their construction. Suffice it to say that it is possible to measure the quantity of oxygen and the quantity of carbon dioxide in a specimen of blood taken from the vascular system. We have already shown that the quantity of gas in a specimen of blood varies with the tension of that gas, also is influenced by the coefficient, so we have arrived at a basis of relation between quantity and tension. The coefficient of a given gas is always the same, so we measure the quantity of gas in a substance and from our findings compute the tension. The value of this is apparent, because if tension expresses pressure, and gas always passes from a high to a low pressure, then gases in one substance alter their position, dependent upon the pressure of that same gas in the tissues around the first.

CHAPTER XXXIV

INNATE CONTROL OF OXYGEN TRANSFERENCE

By analyzing the external air, the alveolar air, the arterial blood and the tissue cell and measuring the quantity of oxygen contained in them it is found that the tension of oxygen in atmospheric percentages is 20, 13 to 16, 14.1 and 0 respectively. In the case of carbon dioxide, its quantity has been measured in the tissue, venous blood, alveolar air, and external air, and its tension measured by atmospheric percentages is about 6, 4.5, 3 and .05 per cent respectively. By studying these figures and bearing in mind that gases pass from a substance of high pressure to one of a lower pressure, we may readily see how the oxygen passes from the external air to the alveolar or from a pressure of 20 to one of from 13 to 16. Now if we take the highest approximation which is given for oxygen tension in the alveolar air and assume that this is the true tension, it is easy to realize how the oxygen passes through the thin walled pulmonary alveoli and capillaries, from the alveolar air to the blood, where the tension is only 14.1, and it is just as easy to realize how the oxygen is then transmitted to the tissue, where the oxygen tension is 0.

In brief physiologists have attempted to explain the passage of oxygen to the lungs, thence to the blood, and finally to the tissue cell, by the laws of physics. We cannot deny that these laws do manifest themselves, but it should not be overlooked that the body is a living unit, and as such is under the control of Innate Intelligence, which governs its actions through the nervous system, thus producing those conditions whereby the physical laws are able to manifest themselves. We do dispute the fact

that this action may well be explained without the consideration of a vital energy controlling the cells of the lungs, and, in fact, every part of the body where oxygen is utilized.

The measuring of the oxygen tension in the alveolar air is extremely difficult, and many observers claim that it is lower than in the blood. It will be noted that the estimate given is from 13 to 16. If it is 16 it might be supposed that the interchange could be accomplished without the expression of Innate, but if this is the case why would it not continue after death? We cannot in any of our considerations assume that the activities of the body in any of its parts can continue normally without the expression of Innate. Innate must be expressed in the contraction and relaxation of the heart in order that there may be a fresh supply of carbonated blood supplied to the pulmonary capillaries at all times. Innate must express herself in the form of muscular contractions in order that fresh air may be taken into the lungs with which to supply this carbonated blood. Innate must express herself in exerting a selective influence upon the oxygen in the blood, wherever it comes in contact with the tissue cells which need this oxygen in their metabolism.

The body is a living unit. Then every part of the body is a living unit and each cell of which it is composed is possessed of the qualities of life. There is material present, but the difference between this material and a material which is dead is the fact that the former is possessed of a vitality and in the case of the human body this vitality is supplied through the nervous system. The pulmonary alveoli are formed of flattened polyhedral cells, which are living units of the human body, just as the cells of the liver, the pancreas, or any other part of the body. The liver cells express the power, under the direction of Innate, of taking from the blood, lymph and serum, which bathe them, the materials which they need to form bile. The cells of the salivary glands have the peculiar ability of taking from these fluids the materials which they will need in the formation of their

part of saliva. In other words, Innate, through these cells in the glands, is possessed of the power of selecting certain materials and passing them through the cells, discharging them at the other extremity in a different form, and thus causing them to carry on their anabolistic process in the body. It is our claim that this is also true of the cells of the pulmonary alveoli. Innate is possessed of a selective influence, which enables her, through the alveolar cells, to take from the alveolar air which comes in contact with them the oxygen, to pass this oxygen through their bodies and present it to the blood, by which it is carried and distributed to all parts of the body. It is probable that the question of tension may also be involved, but this is only a condition existing in response to the controlling influence of Innate.

In considering the question of the exchange of carbon dioxide from the tissue cell to the blood, thence to the alveolae, thence to the external air, it would appear that the difference in tension would of itself account for the change, but because this might occur, is not necessarily an argument that the vital factor must be eliminated in the process. It is absolutely impossible for the interchange to occur without the consideration of the vital factor, because upon Innate Intelligence rests the control which is productive of those conditions which allow the laws of exchange of gases to manifest themselves.

CHAPTER XXXV

INNATE CONTROL OF RESPIRATION

The respiratory center of the brain is a small area at the tip of the calamus scriptorius, near the sensory center of the pneumogastric nerve. In speaking of the various centers of the brain we refer to those particuar areas where the nerve fibers from a certain part of the body or those concerned in a certain action have their central origin. Innate Intelligence acts in sending mental impulses through all the nerve fibres to all parts of the body, but those which are used in the process of respiration are started in that small area where the nerve fibers supplying the muscles of respiration originate, and which is called the respiratory center. It is probable that this respiratory center consists of two divisions, an inspiratory and an expiratory division, in one of which are originated impulses which cause the muscles of inspiration to contract, while in the other originate impulses which cause the muscles of expiration to contract. Some investigators claim that there exists only the center of inspiration, and that expiration occurs merely as an act wherein the elastic tissues of the lungs and thorax return voluntarily to their normal position. It is probably true that the expiratory center is much less active than the inspiratory center, because the muscular effort which is required in quiet inspiration is much greater than that required in quiet expiration. In fact it is reasonable to suppose that expiration is merely the return of these tissues of the thorax to their normal position, and does not involve any muscular effort whatever. So far we have established the fact that Innate sends out mental impulses to the muscular tissues producing a contraction and thus altering the shape and size of the

thorax in such a way that inspiration or expiration of air must follow because of the differences in pressure which are produced by these alterations. At the height of inspiration, an impression traverses the afferent nerves, thus acquainting Innate with the increased quantity of air in the lung cavity, and she inhibits the impulses being sent out over the efferent nerves for a long enough period to allow the elasticity of the lungs and thorax to return the lungs to their former position, thus expelling the tidal air contained in them. After this air has been expelled Innate is again made aware of the fact that oxygen is needed, through the impressions which are again sent over the afferent nerves. This knowledge is gained by the interpretation of the impressions, after which impulses are again sent down to the muscles of inspiration and the entire act again is repeated.

Relation of Circulation to Respiration

That the heart beat is affected in its rapidity by the respiratory movements can be shown by recording the contractions of this organ, and at the same time recording the inspiratory and expiratory movements. Such a record shows that when the inspiratory effort takes place there is an increase in the rate of the heart beat, while during expiration this rate is materially decreased. Why does this change occur? During inspiration the ratio of oxygen in the pulmonary alveoli is constantly increasing, while during expiration it is constantly decreasing. It is the work of the blood to take up the oxygen and distribute it to the various parts of the body, and to give off carbon dioxide. These changes are accomplished, as we have shown, in the lungs, and in explanation of the rapidity of the heart beat and its alterations we may say that when the degree of carbon dioxide is decreasing Innate is made aware of this condition through the afferent fibers, and sends inhibitory impulses to the heart which retard its action. When inspiration begins again, Innate again becomes aware of the increase of oxygen and the decrease of carbon-dioxide proportionately, through the impressions of afferent

fibers and sends out impulses which accelerate the heart action. It can readily be seen then that the increased action of the heart during inspiration is an intellectual adaptation and dependent for its impressions upon the chemical composition of the gas in the pulmonary alveoli.

There is, however, another change which occurs almost syncronously with the respiratory changes, and that is the blood pressure in the arteries of the thorax. When inspiration takes place the arterial pressure increases, and when expiration occurs the arterial pressure decreases. The reason for this change lies in the elasticity of the lungs seeking to change their position at all times. When a normal expiration has just taken place it is found that the lung tissue is still on the stretch, tending to recoil from the thoracic wall, and this would be accomplished were it not for the pleura holding it out in position, because of the vacuum between its two layers. If a cannula be introduced in the pleural cavity at this time it will be found that the vacuum is causing a suction influence enough to draw up 5 to 7 mm. of mercury. In other words the pressure here is -5 to -7 mm. mercury. We will now assume that an ordinary inspiration is taken. If this occurs the lungs are stretched even further than they were at the end of a normal expiration, and as a result are exerting a greater recoil tendency on the thoracic wall. This means that a cannula introduced into the pleural cavity at this time would show a suction influence of about -30 mm. mercury. Summing up, then, the degree of pull exercised by the lungs on the thoracic wall at the end of inspiration is greater than that exercised during inspiration. It should be remembered, however, that the pleura which entirely surrounds the lungs is attached not only to the thoracic wall but also to the mediastinal viscera, which includes the heart, the oesophagus, the thymus gland, and the great vessels entering and leaving the heart. It is only with the vessels and the heart that we are interested at the present time, however. As the lungs tend to pull away from the thoracic

wall they also tend to pull away from these vascular structures. When this occurs greater resistance is offered to this tendency by the heavy arterial walls, while the walls of the veins are thin and weak in comparison. By pulling out on the walls of the veins a partial vacuum is produced in them and they must offer a suction influence because their pressure is lowered. This is exactly what follows, but the blood cannot get back from the ventricles, because of the auriculo-ventricular valves, and it can only be drawn in from the smaller veins of the venous system. The blood, therefore, from the small veins rushes in to fill the partial vacuum and increases the venous pressure, and this increased quantity of blood is immediately forced on into the ventricles, and from them into the arteries, where it raises the blood pressure. Now, when expiration takes place the elasticity of the lungs recoiling, tends to increase the intravenous and intra-auricular pressure which acts in holding back the blood in the venous system into the small veins. The same quantity of blood then is not passed on into the ventricles, and so is not forced out into the arteries, thus the pressure in them decreases. It can readily be seen that it takes some little time for these changes of pressure to take place, and be propagated from the auricles to the ventricles, and thence to the arteries, and it is for this reason that the rise in arterial pressure occurs just following inspiration, while the decrease occurs just following expiration. In some animals where the breathing is very rapid, the rise of arterial pressure due to inspiration does not occur till the beginning of the next inspiration, but if the rate of respiration is decreased the change is seen to occur while the primary inspiration is in progress. Another factor which aids in producing this change in pressure is the abdominal pressure being increased with inspiration because of the descent of the diaphragm and the compression of the abdominal viscera. This helps the suction influence in the great veins and auricles of the thoracic cavity in that it drives the blood from the abdominal area into them.

If the thorax is opened and air allowed to enter the pleural cavity the animal is no longer capable of breathing. However, if it is kept alive by artificial respiration, it is noted that there are variations in the arterial pressure with each respiration, and the investigator would naturally suppose that the explanation just given would fall down because it involves the change in intrapleural pressure. Close examination, however, reveals the fact that these changes in arterial pressure occur in the reverse direction than that in normal breathing. When inspiration is produced the capillaries of the pulmonary system become constricted and dam back the blood in the pulmonary arteries, right heart and great veins of the systemic system. This necessarily cuts off the blood supply of the pulmonary veins to some degree, and thus the proper amount of blood cannot reach the left auricle and ventricle and aorta, so the pressure during inspiration is decreased in the arteries. Again during expiration the lumen of the pulmonary capillaries is increased and the blood is allowed free passage to the left heart, and so the pressure in the aorta during this period is increased.

Necessity of Respiration

Thus far we have considered the action of the lungs in inspiring and expiring air, and the manner in which the elements making up the air and the blood becomes interchanged. We have also considered the innate factor which has to do with the regulation of the respiratory movements, but as yet we have not considered to any great extent the use which the oxygen has in the tissue cell of the body, nor the manner in which the carbon dioxide is produced in the tissue cell. Not only is carbon dioxide expelled from the blood to the pulmonary alveolar air, but also a certain amount of water finds its exit in this manner.

The air is made up principally of carbon dioxide, oxygen and nitrogen and the amount of water which is contained in it varies. In the expired air it is found that the nitrogen is practically the same as that found in the inspired air, but that the

oxygen is decreased and the carbon dioxide is increased, while the water in the expired air causes it to be saturated. This leads to the conclusion that carbonic acid and oxygen alterations constitute practically the only changes with the exception of the alterations in the degree of saturation of the air with water. The oxygen is taken up by the blood and carried by it in the form of a compound known as oxyhaemoglobin. Upon reaching the tissue cell the oxygen leaves the blood and is used to oxidize certain materials here. Carbon is oxidized and forms carbon dioxide, which is carried from the cell by means of the blood and transported to the lungs where it passes into the alveoli and thence to the external. Not all the oxygen which enters the cell, however, is used to oxidize the carbon; hydrogen which is contained in the fats and the proteins is oxidized to form water and much of the oxygen returns to the lungs without being altered at all.

Having just considered the necessity of respiration it leads us to the consideration of certain diseases which may be the result of deficient oxygen. The Chiropractor maintains that all diseases are the result of a lack or excess of mental impulses supplied to the cell from the Innate Intelligence through the medium of the brain system. We, however, do not maintain that a proper amount of oxygen is not necessary, that the proper foods are not necessary nor that temperature does not have its effect on the physiological activity of the body. Physiology includes the study of every organ in the body as regards its function and is the basis for the study of symptomatology. The tissue cell, however, needs something more than mental impulses to make it a one hundred per cent efficient unit. It must have oxygen supplied from the blood, it must have nutritive materials carried to it by the serous circulation, and these all combine to carry on the normal metabolism in the body. True, if the oxygen supply to the lungs is cut off by trauma, the blood cannot receive its proper quantity and thus the process of oxidation in the tissue cell is stopped. This results in the tissue cell failing to function, due to a lack of

material with which to carry on its chemical action, under the control of Innate, and in a very short time death is the result. We do not pretend to say here that an impingement of nerves caused the incoördination and death, on the reverse the mental impulse supply might have been normal, but on account of the traumatic condition the oxygen was cut off, the carbon dioxide poisoned the tissues and made them unfit for their special functions. Again if an individual, against the call of his normal desire, took one kind of food and one only, to the exclusion of other foods, he would soon become nauseated and the food taken would be expelled by Innate, as an adaptative measure. Sickness here would not be due to a nerve impingement, but rather to an unnatural food supply. Let us then remember that Innate can only do her best when the conditions under which she must functionate are normal. So long as one is clean to allow for the excretion of poisons from the skin, so long as the individual receives a reasonable quantity of pure air, pure water and food, health will be the result, providing there is no obstruction to the passage of mental impulses from the brain to the tissue cells.

SECTION VII

CHAPTER XXXVI

SECRETIONS AND EXCRETIONS

In the study of the body as a living unit, we find that a very large percentage of the substance of which it is composed is fluid, and this fluid becomes altered in its passage through the body, so that in one location under certain conditions, with certain substances added to or taken away from it, it is known as one material, while in another part of the body under different conditions, and with different substances in varying proportions, it is known as another.

The question now arises as to how this change in the constituents is produced. Every tissue cell in the body is of a certain structure and is composed of certain characteristic chemical elements. When the fluid which is constantly moving from one part of the body to another comes in contact with these cells, there is usually some interchange of substances of which both are composed, and thus not only is the cell altered, but the fluid is also changed. This alteration is carried on largely in the glands, but is not confined to these structures alone.

In the glands the cells are endowed with that peculiar quality which allows them to become agents through which Innate Intelligence is able to select from the fluids which come in contact with them, those materials which are useful in the formation of the secretion of that particular gland, while the rest is allowed to pass on to other glandular structures, where still different substances are formed. Most of these fluids which are formed by the glandular cells have a specific function and are useful in the

body in maintaining the general metabolism, and when this is the case the substance is known as a secretion. However, when the substance formed is taken from the circulating fluids, because of the selective influence of Innate Intelligence exercised through the cells and is given off from the body as a waste material, which no longer has elements of value which may be used in the body for general anabolism, that substance is known as an excretion. The distinction then between a secretion and an excretion is not in the manner in which either is formed, because they are both the result of Innate Intelligence acting through the secreting cells, rather it is in the character of the substance formed and depends upon the usefulness of this substance in the body.

SEROUS CIRCULATION

The subject of serous circulation is important in that it involves the study of practically every part of the body, and when taken in the broad sense there is not a cell but that has serum in one form or another passing through it. The serous circulation is just as the name implies, the circulation of serum throughout the human body. What is serum? It is defined by Dunglison as "the most watery portion of animal fluids." "It is a constituent part of blood, milk, etc." In brief, wherever we find fluid in the human body there it must be known as serum. Viewing the matter in this broad light, we must think of the fluid portion of the cell as serum, the fluid portion of blood, of bile, of lymph or any other material or part which contains a fluid.

Having determined that all fluid in the body is serum, we have established the fact that the large proportion of the body is serum. We have under the subject of "Secretions and Excretions" shown that the cells and glands of the body are constantly changing, and as they can only change as the materials are carried to them with which to effect this change, we must look for the means by which these substances are carried.

Serous circulation may be divided for the sake of convenience into three divisions. First, we have the blood stream, con-

fined in a definite sea of vessels from which it, as blood, does not escape. However, the blood is largely fluid and this fluid is serum; therefore, one method whereby the serum passes from one part of the body to another is through the blood vessels. Second, we have the lymphatic system which serves to convey lymph from all parts of the body and the intestines to its final termination in the blood stream. It must be remembered, however, that the lymph is largely serum, and thus we have established another means whereby this important fluid is conveyed from one part of the body to another. The third division is the intercellular and intracellular circulation, which as the name implies, is composed of the set of channels within and between the cells, but neither in the vascular system or the lymphatic system.

The vascular system is taken up in a section by itself and there we consider the blood as being largely composed of serum, so that those functions of nutrition, conveyance, etc., may be also considered as functions of serum.

The lymphatic system has also been taken up under a special division, and nothing need be said here in regard to it except that it should be remembered the serum in the lymphatic system is a part of the serous circulation, and the functions which are ascribed to the fluid portion of the former are also functions of the serous system. For example, the function of supplying nutrition to the tissue cells has been ascribed to the lymphatic system and also to the vascular system, but this does not mean that the same function cannot be ascribed to the serous system. Only when we begin to realize the extent which is included by serous circulation, can we realize the importance which it holds to the general bodily metabolism. It is at this time that we realize the difficulty in distinguishing it from, not only the two other important circulations (blood and lymph), but also in distinguishing it from any organ in the body, because it is intimately associated with all of these.

INTERCELLULAR AND INTRACELLULAR CIRCULATIONS

As the name implies, this division includes that portion of the serum which is found between the cells and within their bodies, while not within the lumen of either a blood vessel or a lymphatic. Under this division of the serous circulation may be included the fluid portion of all the cells of the body, and the fluid tissue which has exhuded from the blood vessels and which has not, as yet, found its way into the lymphatic stream. This is the division of the serous circulation by means of which the nutritive elements come into direct contact with the cells. In the case of the blood stream the nutritive elements which are carried are not utilized while in the blood stream, but only become of value as they come into direct contact with the tissue cell. This can only be accomplished through the intercellular circulation.

ORIGIN OF THE SEROUS CIRCULATION

In studying the origin of the serous circulation we must look for the channel through which the fluids of the body gain their entrance. There is only one channel and that is through the mouth at the beginning of the alimentary canal. While we realize that the water which we consume is fluid, we are apt to consider the foods as solid. It must be remembered that the foods are very largely fluid also, and that the materials taken from the alimentary canal are also largely fluid. By what means are these fluids taken from the alimentary canal and distributed throughout the body for the nutrition of all the tissue cells? We are apt to say through the vascular and lymphatic systems, giving little heed to the fact that the open vessel, either blood or lymphatic, is not found in the alimentary canal. Before these fluids can reach these special channels, by which they are quickly distributed to the distant parts of the body, they must enter the intercellular and intracellular circulations and be transmitted by them to the closed vessels.

Certain cells in certain parts of the intestines are utilized by

Innate Intelligence in offering themselves as a channel through and between which certain kinds of food elements may pass, while in other parts other elements are absorbed. This is readily seen in the epithelial cells covering the villi of the small intestines. Here there are seen to be large quantities of fat progressing from the proximal to the distal extremities of the cells, where they are discharged into the basement membrane and thence to the lacteal lymphatic vessel which has its blind origin here. Also it is noted that the cells over the blood capillaries are utilized by Innate Intelligence in selecting especially the proteins and carbohydrates. In conclusion then we may say that it is in the alimentary canal that the serous circulation originates, in that it is from this part that the serum is derived.

PATH OF THE SERUM THROUGH THE BODY

Having established the fact that the serum travels through three distinct courses, it is essential to trace its path through the body to the point of emission from the body. Two of the three paths are taken up in detail under the subjects of the vascular system and the lymphatic system. The third path, that of the intercellular and intracellular is then to be considered.

This is by far the most complicated of the three divisions, because while the other two are confined to a definite known set of vessels, the serum which is found in this division progresses through and between all the cells. We have said that the origin was in the wall of the intestine, and the question now arises as to whether the serum progresses from here to all parts of the body entirely through the intercellular and intracellular system or whether it is first distributed by the lymphatic and vascular systems and is then given over to it. Possibly some of the serum reaches far distant parts of the body entirely through the intercellular and intracellular circulation, but it is probable that the greatest portion of it is carried to the capillaries of the vascular system and from there is distributed to the individual cells by this third division.

TERMINATION OF THE SEROUS SYSTEM

The termination of the serous system may be said to include all the parts of the body where fluid in one form or another is given off. Taking the subject in this broad sense, we may include the kidneys, the skin and the intestines as the three main points of emission, while there are various minor means by which fluid escapes from the body. All of these three main terminals of the serous system are taken up under special chapters; the skin and kidneys under the chapter covering excretions and the intestines under the digestive system.

RELATION OF GLANDS TO THE SEROUS SYSTEM

The relation of the glands of the body to the serous circulation is an important one in so far as the former is the agent through which Innate Intelligence exercises the power of taking from the fluids of the body those materials which are of use in the formation of secretions which are given a definite function in the body. After this power has been exercised the secretion is passed out through a definite duct to a definite organ, provided the secretion is not an internal secretion. If the secretion is an internal one, it is not passed out through an individual duct, but is thrown out again into the serous stream from whence it came and may thus be carried to any or all parts of the body.

All the ductless glands are devoid of special ducts and thus their name is derived. However, the secretions which they form are not allowed to remain in the substance of the organ where they are originated. They are carried in the serum of one or more of the three divisions of the serous circulation to another part of the body where they are made use of. Because these secretions are masked by the serum into which they are immediately thrown upon leaving the secreting cell, it is very difficult to determine their compositions, and thus the functions of some of the ductless glands remain very largely a mystery. Each one of these glands is taken up in a separate chapter dealing with them alone, and the character of the secretion which each forms is detailed

together with its function, provided these points have been accurately determined.

Let us not then underate the importance of the serous circulation. A perusal of the past few pages will convince the reader of the scope which is included by it and the intimate connection which it bears to the entire body in all of its parts and functions. This chapter may be considered as a blanket chapter, which is merely a generalization of the divisions of this important system, and to study the true import of it, consideration must be taken of the fact that every other system of the body must be studied in order to gain a comprehensive view of the serous circulation.

CHAPTER XXXVII

THE DUCTLESS GLANDS AND THEIR RELATION TO THE SEROUS CIRCULATION

There are a number of ductless glands found throughout the entire body, and they vary largely as to shape, size, color, etc. There are some glands such as the liver, pancreas and salivary glands which have ducts leading to other structures, and the function of which is to carry away the secretions of those glands. The ductless glands have no such structures to carry away their secretions, and their name is derived from this fact. This being true the investigator must look about for some method of elimination of the secretion of these glands and he finds it in the serous channels with which they are supplied. Furthermore, he must look for some method whereby the materials from which the secretions are made, will be supplied, and he finds these also in the serous vessels which carry serum to the glands.

It is true that we are well acquainted with the function of these glands in the body which form a fluid, and possess ducts, so that we are enabled to trace the secretion to the structure for which it is meant, but when the secretion is merely poured into one of the channels of the serous circulation, and is so conveyed apparently to the entire body, it is a much more difficult matter and today Chiropractic offers the first explanation as to the true functional importance of this activity. So far investigators have only been able to conclude, from the fact that the secretions come in contact with practically every tissue of the body, by means of the serous channels, that they have some general metabolistic effect upon all these tissues. It is because of the fact that the secretions formed are made up of materials taken from the serous

circulation, and are again poured into it, that they are known as internal secretions. Some of the glands which are supplied with ducts form secretions which are not sent out through these ducts (pancreas and liver) and they are called internal secretions also. Some of these internal secretions are absolutely essential to life, while the absence of others will not cause death, due to the fact that a similar secretion is supplied, by an adaptative process of Innate, from some of the other glands resembling them in structure and function. Either this condition must exist or their secretion, while important in the production of health, is not essential to life.

There is an unlimited amount to be said in regard to the ductless glands, and yet until now very little has been said, for the reason that investigators, while gaining knowledge in regard to them all the time, still were unable to arrive at a great deal of definite material with which they could acquaint us.

There are really two theories which are advanced today in regard to the general function of the ductless glands, one of which is known as the internal secretion, and the other as the auto-intoxication theory. The former we have briefly mentioned, and is to the effect that the fluids formed by them are formed for a definite use in the body, and control many conditions here. The latter is just what the name implies and according to the believers in this phase, the fluids manufactured are in the form of an excretion, and they combine the chemicals which are no longer necessary in the body in such a way that they may be easily excreted by the excretory channels of the body. If death then ensues after the extirpation of one of the important ductless glands, the claim is made that it is because of auto-intoxication, due to the fact that the poisons cannot be eliminated from the body.

It is left for the Chiropractor to offer his principal and prove it by logical and conclusive arguments. Heretofore investigators have made the mistake in the study of the ductless glands, as in

practically every other system of the body of considering each gland as a separate and individual organ which has nothing to do with the other organs of its system. The Chiropractic idea includes each and every ductless gland under the same great system, and having already established the fact that the serous circulation is an intricate system involving every part of the body, it must also be granted that it is the medium by which every one of these ductless glands must be connected, one with another. This being true, we have before us the picture of an entire system, each ductless gland being a unit in this system, and the serous channels as the connection link. Further, we have a definite starting and a definite ending of this secretory system. It begins in the serous channels around the intestinal tract and terminates in the kidneys and the skin.

In enumerating the ductless glands we may include the lymphatic glands, the haemolymph glands, the pineal, the pituitary body, the carotid glands, the thyroid, parathyroids, thymus, spleen, suprarenal glands and the coccygeal gland, making in all eleven different varieties. We will now take up the study of each of these glands separately, first describing them and afterward explaining their functions and their importance.

LYMPHATIC GLANDS

The lymphatic glands, or lymph nodes as they are sometimes called, vary greatly in size in the different parts of the body, and may be all the way from the size of a hemp seed to the size of a large olive. In color they are not constant, being of different hues and shades in the different locations (bronchial nodes are mottled, hepatic nodes yellow), but we may say of the majority that they are of a pinkish gray color upon cross-section and are kidney shaped.

Lymphatic glands are usually arranged singly, although they are sometimes found in groups of a dozen or more. The most common locations for them are in the abdomen and thorax along the course of the large blood vessels; also in the axilla, groin and

neck. There are a few of them in the upper and lower extremities, but they are not found further down the leg than the knee, nor further down the arm than the elbow.

In structure the lymphatic node is surrounded by a fibro muscular connective tissue, which acts as a distinct capsule, and from this capsule are sent in prolongations, composed of the same kind of tissue, and these prolongations are known as trabeculae. They anastamose freely, one with another, although more freely at the interior of the gland than near the surface, thus giving rise to a coarse network externally and a fine one internally. These peculiarities form the cortical and medullary divisions. The lymph node has upon one side a slight depression giving it the peculiar shape of a bean, and it is near this depression that the medullary substance is placed. Not only in the size of the meshes of the two divisions is there a contrast, but also there is some variation in color, the medullary portion being of a dark pink shade and the cortical substance of a lighter pinkish-gray. In the interspaces of these anastamosing trabeculae we find the true lymph tissue, which is also found in other parts of the body, not surrounded by a capsule, and it is this tissue which is the real functioning part of the lymphatic gland. In structure it is of the retiform variety of connective tissue, and contains many white fibers. In the interspaces between these white fibers we find large quantities of white corpuscles known as lymphocytes, together with a great deal of lymph, serum and blood. This central tissue, however, does not come in contact directly with the trabeculae nor the capsule, but is separated from them by a very few fibers of white connective tissue, and it is this small interspace that is known as the lymph path. It is through this less dense network that the greater quantity of serum passes on its way through the gland. The entrance of the lymph into the node is by means of several small branches of a main lymphatic vessel, which are formed by a subdivision just before the vessel enters the substance of the structure, and these small subdivisions of the main

vessel which enter are known as the afferent vessels. Their outer coat is prolonged to the outer coat of the capsule, and their lining of endothelium is continuous with the lining of the lymphatic gland. These afferent vessels enter at the convex portion, and after the lymph has passed through the gland it is carried away by several small vessels which are known as the efferent vessels. These efferent vessels leave at the hilus and join immediately or soon after. The glands are also richly supplied with blood by small arteries entering at the hilus, and whose corresponding veins also emerge here.

We will consider the function of the lymphatic gland more fully when we consider the lymphatic system, but at this time we may say that its principal function is the formation of white blood corpuscles, known as lymphocytes, which are afterward emptied into the blood stream and become a form of leucocyte.

HAEMOLYMPH GLANDS

There are glands in the body, which in shape, size and structure, are very similar to the lymphatic glands, but in color are of a deep red, and are named the haemolymph glands. They may be found in various parts of the body, but are most common in the abdomen just anterior to the lumbar vertebrae. Some investigators claim that they contain pure blood, and some contend that they contain at least part lymph. As a matter of fact they contain a large quantity of serum, but some are more richly supplied with blood vessels and, therefore, the serum in this type contains a larger amount of haemoglobin and is redder in color. There are two types with no hard and fast line of demarkation between them; they are called the haemal glands and the haemal lymphatic glands, so classified merely because one type contains serum with many corpuscles, and the other contains serum with comparatively few.

It is the function of the haemolymph glands under the direction of Innate Intelligence to take from the serum which passes through them those materials which are necessary in the manu-

facturing of lymphocytes, to manufacture these important little bodies and start them on their journey through the serous system to their ultimate destination among the blood corpuscles.

PINEAL GLAND

The pineal gland or epiphysis, as it is sometimes called, is a small reddish-gray body, and resembles in shape a pine cone; hence the name (pinus). It is located at the posterior and inferior to the corpus callosum, resting upon the quadrigemina. In structure this small gland is formed of follicles which communicate in the center, and are lined with epithelium. These follicles are full at all times, of a clear viscid fluid containing a gritty matter, which is known as brain sand. This brain sand is composed of phosphate of magnesia, phosphate of ammonia, phosphate of lime and carbonate of lime, together with a slight amount of animal matter.

This little body, although located within the cranial cavity and in contact with the brain substance, nevertheless is supplied with nerve fibers, and through these fibers Innate controls its actions in every detail. She takes from the serum which comes in contact with the gland materials which are utilized in the manufacture of its peculiar secretion, and having formed this secretion pours it into the serous stream, and it is thus carried to all parts of the body. It is found that when this gland is diseased the symptoms which are manifested are those of a deficiency, both mentally and physically. Not only does the mind seem to be devoid of the power of development, but the body remains small and weak. From these observations it is concluded that the pineal gland secretes a brain sand which is utilized in all parts of the body by every cell of the body, that growth may progress normally.

THE PITUITARY BODY

The pituitary body or hypophysis, as it is sometimes called, is a small structure located in and almost completely filling the sella turcica of the sphenoid bone. It is composed of two separate and

distinct structures, both of which are derived from the ectoderm, but one of neural tissue and the other of glandular structure. These two divisions, one anterior and the other posterior, give rise to the descriptive names prehypophysis, and posthypophysis, the prehypophysis being a prolongation of the primitive buccal cavity, and composed of glandular tissue very similar in structure to the para-thyroid glands, and the posthypophysis being derived from the brain and composed of neuroglia, connective tissue and blood vessels. The anterior division is of a yellowish color, while the posterior division is of a whitish color and of a pulpy nature. Upon the interior of the glandular structure there are spherical alveoli which are filled with nucleated cells and these cells are surrounded by colloid substance.

We know that the post mortem examination of the brain of a subject suffering from acromegally shows some disease of the pituitary body, either tumor or some other pathological condition, and this leads us to the knowledge that a deficiency in its secretion is productive of the symptoms of this disease. Acromegally is characterized by an overgrowth of the bones of the face and hands, especially the mandible. There is also a mental deficiency which is very marked and indicates that while the development of the bones progresses too rapidly, the mind is unable to develop as it should. The physician has progressed part way toward the goal of truth in realizing that the abnormal condition of the pituitary body is productive of acromegally, but there he leaves the channels of constructive reasoning, and instead of proceeding to the cause of this abnormality in the pituitary gland, he attempts to analyze the secretion and then manufacture it, that the deficiency may be thus supplied. Pituitary extract is produced and given to the patient suffering from acromegally, and while it cannot be denied that some good results, the basis is fundamentally wrong. The Chiropractor finds the cause of the abnormality in the pituitary gland is due to a nerve impingement which partially shuts off the mental impulse supply to this important

gland, and when this condition is relieved the pituitary body must be normal and health will be the result. We may conclude then that the pituitary gland forms a secretion which is passed out by means of the serous circulation to every part of the body and that this secretion, like that of the pineal body, has to do with the process of expansion, especially of the cells of those bones which are found in the face and hands. This secretion is further of value in producing the normal activity of the brain cells that mental development may progress.

CAROTID GLANDS

The carotid bodies or glands are, so far as functional importance is concerned, relatively unimportant, because their absence or deficiency does not lead to any marked incoördinations. Observations upon foetuses point to the fact that they are developed, if not after birth, at least during the latter part of the intra-uterine life, and sometimes they are only rudimentary or developed upon only one side. In size the carotid glands are about that of a grain of corn and in color of a reddish brown tint. They lie directly in the bifurcation of the common carotid artery one on either side, and are connected to this structure by a thin band which is known as the ligament of Mayer. In structure the carotid glands are surrounded by a fibrous capsule, and this capsule sends in trabeculae which divide the organ into follicles. The follicles contain masses of epithelial cells so closely packed that they are known as cell-balls, and closely associated with these cells are masses of capillaries, intermingling and making these small glands very vascular. The supply of this blood comes from a small branch of the carotid artery which pierces the ligament of Mayer on its way to the gland. Around the outer surface of the carotid gland we have a great number of nerve filaments which usually form a plexus known as the intercarotid plexus, and it is because of this fact that for a long time the carotid glands were thought to be ganglia.

The carotid glands have the same function as the lymphatic

glands do, namely, to manufacture lymphocytes. It is for this reason that the effects which are noted upon their removal is so slight or entirely absent. Innate utilizes many hundreds of these lymphatic glands over the entire body to manufacture these lymphocytes, and while no gland can have its secretion manufactured by another gland, still if there are many units in an entire system, each one of which does work similar to that of every other unit, the effect of the absence of one is comparatively small.

THYROID GLAND

The thyroid gland is a body of extremely vascular structure situated at the sides and front of the neck, and forming in this way a semi-circle around the larynx. It varies in size, but is relatively larger in the female than in the male and is found to enlarge somewhat during the time of pregnancy and menstruation. During the first few weeks of embryonic life there exists a small duct from the gland extending upward to the buccal cavity, opening here by the foramen caecum on the dorsum of the tongue. The average weight of the gland is about one ounce, but is relatively heavier in children than adults. From adult life it gradually diminishes in size until old age. In color the external of the thyroid is of a bluish-red, and in shape it is very irregular. It consists of two lobes connected by a small strip, which is known as the isthmus, and sometimes arising from this isthmus there is a pyramidal shaped strip forming a third lobe, known as the pyramidal lobe or middle lobe. When it is present it follows the course of the thyroid duct as followed in foetal life, but does not extend as far as the foramen caecum. These two lateral lobes of which we have spoken are situated one on either side of the outer surface of the larynx and upper portion of the trachea, and are closely adherent to them. The isthmus and the middle lobe, if the latter is present, are between the two lateral lobes, the isthmus connecting them at the anterior, and the middle lobe extending from the isthmus, with its base resting thereon, to about the level of the hyoid bone. There are small bodies constructed of thyroid

tissue, which are often found close to the thyroid gland, but are entirely independent of them so far as the structural connection is concerned, and these are known as accessory thyroids. Functionally they seem to have the same purpose as the thyroid gland, and are merely isolated masses of its tissue.

Surrounding and completely investing the thyroid gland we find a thin capsule of connective tissue, which projects into the substance of the organ dividing it into separate and distinct divisions which are known as lobules. These lobules are further divided into smaller divisions known as alveoli by extremely thin walls of connective tissue. Upon cross section the color of the gland is found to be that of a reddish-brown, and to be composed entirely of these small alveoli separated by the connective tissue and the substance which is found in the alveoli, which is of a viscid yellow, glairy nature. These alveoli or vessicles do not communicate with one another, but are completely isolated, and each one is lined with a single layer of epithelium, of a cubical or cylindrical type. These vessicles are not of a constant shape, but the color of the fluid substance which they contain is always of the peculiar yellowish glairy character. We find upon examination that this fluid contains a great many red blood cells in the various stages of disintegration, and it is during this process that the liberation of haemoglobin occurs, which produces the peculiar character of the fluid contained. This fluid is known as colloid material and is produced by the secretory action of the epithelial cells. There are present between the vesicles and in the substance of the intervesicular material, groups of small cells which in reality, are very small vesicles. It is supposed that these small vesicles or alveoli become expanded, as age advances, and become large vesicles, and this idea is supported by the fact that they become less numerous as years advance from childhood up.

The thyroid gland is richly supplied by blood vessels as are all the ductless glands, and these vessels are the superior and inferior thyroid arteries and the thyroid ima (sometimes present)

which carry the blood to the gland, and the superior thyroid, inferior thyroid, superior accessory, inferior accessory and thyroid ima veins which carry it away. The blood vessels upon entering the organ pierce the capsule, and branching, these branches follow the course of the trabeculae to the interior, where they divide and subdivide, forming finally a capillary network in the thin fibrous septa, and from there the blood is picked up by veins and finally eliminated from the gland. It is in the capillaries of these fibrous walls that the blood comes nearest the secretory cells of the gland, but it is erroneous to state that the cells take from the capillaries the materials which are necessary in the formation of their secretion. Innate supplying the walls of these capillaries, takes from the blood, serum, and passes it out into the surrounding spaces. This serum is now in direct contact with the secretory cells and through them Innate exercises her selective ability in choosing just those substances which are necessary in compounding the colloid substance. These substances are passed through the cells and are finally thrown off into the alveoli as the finished product. This colloid material is then the internal secretion of the thyroid gland.

Extirpation of the glandular substance in part is often accomplished and is very common as an operation for goitre, but if all the substance of the gland is removed death finally results, preceeded by the characteristic symptoms of myxodema. Not only is myxodema found in extirpation of the gland, but in diseased conditions of this structure we also have it appearing, if the disease is of such a nature that the function of the gland is interfered with. Furthermore, we know that if the secretion of the gland is injected or fed to the individual suffering from myxodema, the symptoms are in measure relieved, and the same results are obtained if an extirpated gland is grafted into the abdomen of the patient and the grafting takes. Here also the scientist has only half completed his reasoning. If the thyroid is diseased and the symptoms of myxodema appear, why treat the effect of the ab-

sence of its secretion. The Chiropractor maintains that this diseased condition of the thyroid is due to a subluxation which produces an abnormality in the mental impulse supply to this gland. He corrects the subluxation and immediately the thyroid gland resumes its normal functioning, and health is the result.

During the process of study of the substance known as colloid substance of the thyroid, there has been isolated from this secretion a substance known as thyro-iodin or iodo-thyrin, and it is well established that this is the essential functioning part of the secretion, for by its injection practically the same results are obtained in myxodema as by the injection of the entire secretion. This is of value only in so far as it isolates a particularly powerful element in the colloid substance, but does not prove that the balance of the secretion is valueless. In fact Innate never wastes energy, and if a secretion is formed it must have some metabolistic effect upon the body. True, it may not be essential to life, but it is always essential to health.

After the colloid substance has been formed as we have related in a previous paragraph, it is poured into an alveolus which has no apparent means of exit. The alveolus begins to enlarge then, and finally stretches the walls of the alveolus to such a degree that they rupture, and the secretion is allowed to pour into the surrounding connective tissue walls. It now becomes a part of the serous circulation and is carried away as such to all parts of the body.

This colloid substance has the function of offering itself, under the control of Innate Intelligence, as an agent which joins with certain other chemicals in the connective tissue cells over the entire body, and thus the combination becomes a metabolistic agent. If, however, the thyroid gland becomes abnormal from an incoördination in the mental impulse supply its secretion is not properly formed and there is no combination of it with the other substances. When this is true we have enlarged connective tissues and the characteristic spade hand and moon face due to this inability to utilize the substances contained therein. There

is also no question but that this colloid substance has an important function in supplying the cells of the brain with nutritive materials, and when it is absent or deficient we have a mental deficiency which is directly the result.

PARATHYROID GLANDS

The parathyroid glands are small, disc shaped bodies, about a quarter of an inch in length, an eighth of an inch in breadth, and are situated closely in relation with the thyroid gland. There are as a rule, four of them, of a brownish-red color, but there may be two, three or even as many as six or eight. When there are four present they are divided into the superior and inferior. The superior located at about the level of the cricoid cartilage, and at the posterior of the thyroid behind the junction of the pharynx and the oesophagus. The inferior are located at the inferior border of the thyroid gland and at the posterior of the lateral lobes, or they may be found connected to the substance of the inferior thyroid veins.

In structure they differ from that of the thyroid gland in that they consist of masses of cells arranged in recticular fashion and with a great many intervening blood vessels. These cells are arranged in chain-like manner and the intervening connective tissue contains not only large quantities of blood vessels, but also a great deal of lymphatic tissue and lymph, which has a similar function to that of the blood vessels. It must be remembered that these are two channels for the transporting of serum throughout the body and where the function of serum is to supply nutritive materials to the tissues and carry away secretions and waste, it must necessarily be also the function of these important vessels.

Each parathyroid gland is supplied by parathyroid arteries, the superior and inferior, which are derived usually from the inferior thyroid artery, but the superior one of these may be derived from the superior thyroid artery.

Until this time it has been a matter of dispute among investi-

gators as to the exact function of the parathyroid glands, some of them contending that they perform the same function as does the thyroid, and others claiming that they have a separate and distinct function in themselves. Certain it is that there is no thyroiodin in their secretion, and it is equally certain that their removal is followed by the symptoms of tetany. Their disease also gives rise to very serious symptoms, and death usually results as a consequence of their inability to function. Chiropractic advances the idea that these small glands are indispensable to the general metabolism because Innate utilizes them as agents to take from the body certain substances which, if remaining free, act as toxins. If the expression of Innate Intelligence is hindered by a subluxation we have an inability of the glands to properly perform their function and as a result the retaining in the body of poisons, which give rise to the various symptoms of tetany and finally death from auto-intoxication.

THYMUS GLAND

The thymus is a single gland situated in the superior mediastinal space and in the neck, extending from the level of the fourth intercostal space to the level of the inferior border of the thyroid gland. It is flat, being about two inches in length, one and a half inches in breadth and a quarter of an inch in thickness. More or less pyramidal in shape, it consists of two lobes, a right and a left, although sometimes there may be found a third lobe, which is found between the two lateral. It rests below upon the pericardium, and is separated from this structure and the great vessels which emit from it by a thin layer of fascia. Extending upward it lies just below the sternum and the sterno-hyoid and sterno-thyroid muscles and is closely adherent to the substance of the trachea.

It must be understood that the thymus is distinctly a temporary organ so far as functioning ability is concerned, possessing its greatest size at about the second year of life, maintaining that size until puberty, when it gradually diminishes until in adult life it is merely a rudimentary organ.

The entire gland is surrounded by a capsule of fibrous tissue which sends in trabeculae, dividing the gland into lobules, varying in size from that of a pinhead to the size of a small pea. These lobules are peculiar in that they consist of a cortical and medullary portion, the former on the outside, and the latter in the center of the lobule. The cortical portion consists of a very dense lymphoid tissue containing a dense reticular network, and containing in this network many lymphocytes. The medullary portion, on the other hand, contains a reticular network of much looser construction, and one in which the corpuscles are not so concentrated. There are two kinds of corpuscles or cells in this portion, one of them known as the granular cells, which are branched and help to form the network of this substance, the other known as the concentric corpuscles of Hassal, and are much larger than the former. It is supposed that the concentric corpuscles of Hassal are derived from the epithelial tissue of the pharynx, which have been cut off from their proper location in the process of development, and form small islands in the substance of the thymus.

Each lobule is closely surrounded by a plexus of capillaries, which follows the course of the trabeculae, and of the fine filaments of areolar tissue which proceed from them, and it is from these vessels as well as from the lymphatic vessels that the serum which supplies the thymus cells is derived.

It is true that the thymus gland has interspaces which are filled with lymphoid tissue and for this reason it has long been supposed that the function was to manufacture white blood corpuscles, as does lymphatic tissue in other locations. Chiropractic advances the idea that the thymus gland is vitally concerned in the process of growth of the body, and that the secretion formed by it is utilized in every growing cell of the body. This is borne out by the fact that the thymus gland attains its greatest size and retains this size during the developing period. The testes and the ovaries, while developing, secrete an internal secretion which is utilized in forming the internal secretion of the thymus. This is evidenced by the fact that extirpation of the

thymus allows the testes to rapidly enlarge and also by the fact that castration markedly retards the growth of the thymus gland and the body in general.

SPLEEN.

We have now to consider the largest of the ductless glands, namely the spleen, and may briefly outline its position and size before entering into a discussion as to its structure and function. In size it is about five inches in length, two and a half inches in breadth and an inch and a half in thickness, although its size may vary a great deal from this average. In color it is of a dark purple, and lies in the left hypochondriac region, extending from here possibly into the epigastric region. Located as it is behind the stomach and above this organ, also above the left kidney and below the diaphragm, it does not permit of observation from the anterior without the removal of the stomach. In shape it is variable, but usually is found to be oblong, very vascular and of a soft, loose construction. In adult life the spleen usually weighs about one-three hundred and twentieth of the entire weight of the body while in old age there is a marked decrease in its size, frequently becoming only one-seven hundredth of the entire weight. The spleen has a direct connection with the process of nutrition carried on in the body, and increases markedly during and after digestion. This substance which is manufactured is carried through the serous circulation to the alimentary canal, where it is utilized in the digestion of foods. Much of the substance formed in the spleen is carried to the liver and is utilized in the formation of bile.

In structure this largest of the ductless glands is surrounded by a capsule which consists of two layers, an outer or serous one and an inner or fibro-muscular one. The external layer is derived from the peritoneum and completely surrounds the organ except where it is reflected over the stomach, the diaphragm and at the hilum. The fibro-muscular layer completely invests the spleen and together with the trebeculae which it sends in, forms the

framework of the organ. These trebeculae are of the same structure as the capsule, being composed of white fibrous tissue, yellow elastic tissue and many non-striated muscular fibers. These trabeculae divide the organ into small divisions known as areola, and it is in these areolae that the spleen pulp or true substance of the spleen is found.

This splenic pulp is a dark, soft mass of a reddish-brown color, and when examined under the microscope is found to consist of a great number of branching cells and between them quantities of blood. These branching cells are known as the sustentacular cells or supporting cells of the pulp, because of the fact that their branches join one with another and by so joining, divide the areolae into still smaller spaces which are filled with blood. This blood, however, is found to contain a greater number of white cells that ordinary blood. The sustentacular cells of the spleen are found to be different in shape from the blood corpuscles, but like them possess an amoebic movement, thus at all times changing the size and shape of the interspaces. Sometimes these cells contain one nucleus and sometimes they contain several nuclei; however this may be, it is found that within the substance of the cell there are masses of hematin and red blood cells in various degrees of disintegration. It has, also, been noticed that the nuclei of the cells have adhering to them small nodules which may be nuclei of new cells to be formed, and if this is true it would explain the manner in which white blood corpuscles are formed within the substance of the spleen.

There is a marked peculiarity in the distribution of blood within the substance of this largest of the ductless glands. The splenic artery divides into five or six divisions which enter the spleen at the hilus, and it is here, also, that the splenic vein, the largest vessel forming the portal vein, emits from the gland. The branches of the splenic artery after entering into the substance of the trabeculae, do not anastamose freely, but each pursues a separate and distinct course in itself, dividing and subdividing, until its small arterioles enter into the true substance of the splenic

pulp. Here the vessels undergo a change as they approach their termination, becoming at their extremities a mass of lymphoid tissue rather than the ordinary connective tissue of the blood vessels. This lymphoid tissue gradually becomes thinner and thinner until it has disappeared altogether, and thus the blood from the splenic artery finally finds its way into direct contact with the splenic pulp. There are places in the course of the vessel termination where the lymphoid tissue becomes very much condensed and thickened, and these concentrated masses of lymphoid tissue are known as the Malphigian bodies of the spleen. They completely surround the lumen of the arteriole, and thus the vessel seems to pierce their very substance. The veins find their beginning in very much the same way that the arteries terminate, and gather up the blood in the spleen by an open brush-work, composed of lymphoid tissue. These small venules unite and reunite until finally the splenic vein is formed. The veins are remarkable because they anastamose so freely, and the arteries because they do not anastamose to any great degree.

The function of the spleen is to form splenic fluid for use in the process of digestion. This splenic fluid is poured into the serous circulation when formed and carried by it to the alimentary canal, where it is utilized in the digestion of foods. Innate Intelligence becomes aware of the need of splenic fluid when food is taken into the stomach, and immediately impulses are sent to the secreting cells in the spleen, producing an activity in them. At this time because more serum is needed in the manufacture of splenic fluid, Innate sends down inhibitory impulses to the afferent vessel walls and motor impulses to the efferent walls. This accounts for the enlargement of the spleen during digestion. It must also be remembered that the spleen is composed largely of lymphoid tissue which is utilized by Innate Intelligence in manufacturing lymphocytes. With this in mind it is easy to recognize the reason for the spleen enlarging during fevers or at any time when there are poisons in the body. The lymphocytes are utilized by Innate to absorb toxins and because there are always many

of these in all fevers, the spleen enlarges as an adaptative measure in order that a sufficient number of lymphocytes may be produced to meet the increased demand.

THE SUPRA-RENAL GLANDS

These are two small yellowish bodies placed just behind the peritoneum and resting upon the upper and anterior surface of the kidneys; hence their name. The left gland is semilunar in shape, while the right is triangular and is placed somewhat lower than the left. In size the glands are about two inches in length, one and a half inches in breadth and only two or three lines in thickness, so it can be readily seen that they lie upon the surface of the kidney in the form of a flat organ.

In structure the supra-renal glands are divided into an outer and an inner portion, the former known as the cortical portion and the latter as the medullary. The cortical forms the chief bulk of the gland and is of a deep yellow color, while the medullary is of a dark brown and is of a soft, pulpy nature. The fibers that are sent into the substance of the gland are perpendicular to the surface and have small fibers joining them at right angles. Just next to the capsule these cross fibers are thickly placed and form a distinct layer, known as the zona glomerulosa. Next to them we have long, narrow spaces that are known as the zona faciculata, and below them there exists again a series of short spaces that are known as the zona reticularis. In the interspaces of these various zona we have the soft substance of the gland made up of groups of polyhedral glandular cells with fat contained within their substance. There seems to be spaces of reticular tissue between this pulp and the fibers which are known as lymph spaces, and it is through these openings that the lymph and serum have their passage through the gland. In the medullary substance we find white fibers formed into much closer bundles, thus leaving larger interspaces, and in these interspaces we find quantities of cells of an epithelial character which are very granular and do not contain fat.

The arteries are derived from three sources, the aorta, the phrenic and the renal arteries, and divide into very small branches before entering the substance of the organ. The veins leave the glands at the hilus: That from the right supra-renal empties directly into the inferior vena cava while the vein from the left empties into the renal vein of that side.

The function of the supra-renal gland is to manufacture a substance known as adrenalin. This secretion is taken to all parts of the body by the serous circulation and as a chemical substance offers itself to the muscular fibers of the body that they may utilize the motor impulses with which they are supplied. If the muscle fibers were not supplied with nutritive substances they would be unable to maintain their tonicity, because there would be nothing to build up with. Adrenalin offers itself as a powerful nutritive agent to all muscular fibers. In the supra-renal glands the secreting cells under the direct control of Innate assemble from the serum the materials which are necessary in the formation of adrenalin and pass them through their bodies; thus they become changed and a part of the entire secretion.

COCCYGEAL GLAND

At the tip of the coccyx is located a very small gland varying from microscopical size to the size of a pea. In structure and function it is merely a lymphatic gland, but is designated by that peculiar name because of its location.

In conclusion we may say that after having studied each of the ductless glands individually there can be no doubt but that the only means of entrance and exit from them is through the serous channels, and because of this fact it must be accepted that their secretions, which are peculiar to each one of them, must be widely distributed in the body. This being true, each of them must form a secretion, which is important to the body in general, although it may be more noticeable in one location than in another.

SECTION VIII

THE DIGESTIVE SYSTEM

CHAPTER XXXVIII

STRUCTURE OF UPPER ALIMENTARY CANAL

The digestive system is the system which has to do with the changing of the foods in such a manner that they may be absorbed and assimiliated in the body, that they may assist in the metabolism of the tissue. It includes the alimentary tract, glands, teeth, etc., which serve the purpose of altering the food in any manner necessary for absorption.

The alimentary tract is the tube through which the food passes and undergoes changes in the body. This includes the mouth, pharynx, oesophagus, stomach, small intestines and large intestines. The entire alimentary tract is lined with a mucous membrane which varies in its structure in the different parts of the tract. Just beneath this mucous membrane there is a coat of varying degrees in thickness, composed of connective tissue which is known as the submucous coat. Most of the tract has outside this a muscular coat, which also varies as to thickness, arrangement and importance, and outside this muscular coat exists among most of the extent of the tract, a fourth coat composed in some parts of a serous membrane, and in other parts of a fibrous layer. The walls of the mouth, pharynx and oesophagus are closely attached to the surrounding structures, and admit of little movement except as the surrounding parts move, while the walls of the

stomach, small and large intestines are not so closely attached, and admit of freer movements.

Throughout the entire inner surface of the alimentary tract are many glands located in the walls and emptying their secretions into the lumen of the tube. Also there are glands which are found entirely outside the wall of the canal, which by ducts empty their secretions into its lumen. In describing any of these glands we will use the terms simple, compound, tubular and racemose. The simple glands are those which have just one duct leading from the surface of the mucous membrane into the underlying structures, and this duct is not branched. A compound gland is one which has its excretory duct or ducts branched. A tubular gland is one in which the excretory duct is tubular, but when the appellation of racemose is added, it indicates that at the termination of the tube or tubes there is a dilation. Thus the pancreas which has the excretory duct formed of many tubes which converge and join to empty into the one large duct, is a compound tubuloracemose gland, because there are many tubes and because at the distal end of each tube there is a dilation.

THE BUCCAL CAVITY

The cavity of the mouth is the first cavity which the food enters on its passage through the alimentary tract. The mouth is lined by a stratified squamous epithelium, overlying a basement membrane of connective tissue. This underlying basement membrane is very irregular in shape and shows upon cross section many papillae, which vary in size and shape in different parts of the mouth. Their contour, however, is not apparent except on cross section because the hollows between them are filled with epithelial cells, and when the surface of the epithelium is reached it shows no great irregularity of outline. Placed just beneath the mucous membrane is a layer of connective tissue composed principally of white fibers and with very few elastic fibers. This is known as the submucous coat and serves to attach the mucous membrane to the underlying structures. In the case of the mucous

membrane over the gums and over the hard palate the attachment is direct to the periosteum, while over the softer structures, such as the lips, cheeks and soft palate, the attachment is to the epimysium of the muscle tissue. It is true that the papillae of the mucous membrane are not apparent on the surface, yet there seems to be an irregularity here. This is due to the presence of lymph nodes in the underlying tissues and occurs only in certain areas of the mucous membrane.

Oral glands. With the exception of the mucous membrane attached directly to the periosteum (here a few glands may exist) there are many glands of the compound tubular type emptying into the buccal cavity and having their bodies in the submucous tissue as well as in the mucous lining. The ducts of these glands extend for a short distance into the mucous membrane, where they become branched, and these branches in turn may become branched. The lining of these glands is merely a continuation of the squamous stratified epithelium which lines the mouth, and this type continues till the first branch is reached, when the lining changes to the columnar stratified type, and in the very terminal branches this strata disappears and the simple columnar type persists. The glands found in the mucous membrane may be divided into three classes:

Mucous gland—Those which secrete mucus.

Serous glands—Those which secrete serum.

Mixed glands—Those which secrete a mixture of serum and mucus.

The various types of glands are found in different parts of the mucous membrane and are so named because of the substance which they secrete. Their fluid is determined by the kind of cells with which they are lined. The mixed type is found in all parts of the mouth, while the serous group is found around the circumvallate papillae, and the mucous at the root of the tongue.

In the mucous glands, which are larger than those of the serous type, and also more irregular in shape, the cells are usually cubical, although this shape may vary. The cells are larger and

show a clear protoplasm during activity, but when at rest the distal extremity, where the nucleus is situated, is granular and less transparent.

In the serous glands the protoplasm is granular to some degree at all times, but during activity the granulated appearance becomes more pronounced and the cell thus becomes more opaque. The cells of these glands are variable in their shape, but in main are cubical.

In the mixed glands the lumen is lined with both serous and mucous cells and at the distal extremities of these central cells, between them and the basement membrane are often found semi-lunar shaped cells, which are serous in character and whose secretion is poured into the main lumen by intercellular canals. In the submucous membrane, where the principal part of the tube lies, is a dense plexus of blood vessels and lymphatics from which are derived the materials used by the glands in the formation of their peculiar secretions. These materials are taken in at the distal ends of the secreting cells and after going through a process of change are given off at the proximal extremity into the lumen of the gland.

THE PHARYNGEAL CAVITY

The pharynx is a musculo-membranous tube extending from the base of the skull to the entrance into the oesophagus, opposite the upper border of the sixth cervical vertebra. Conical in shape, it is placed with its apex downward and its base formed by the under surface of the skull. In length it is about four and one-half inches, and has seven openings into its cavity. Two posterior nares, two eustacheon tubes, the oral cavity, the larynx and the oesophagus. It serves the purpose of conveying the air from the nares and mouth to the larynx and from the larynx to the external, and also offers itself as a means of conveying the food from the mouth to the oesophagus.

The cavity of the pharynx is lined with epithelium principally of the stratified squamous type, and distributed over the surface

of this epithelial tissue are the openings of many glands similar in their structure and types to those found in the mouth. The submucous coat is poorly developed in the pharynx and so the mucous membrane lies principally upon the muscular coat. This coat is formed of muscular fibers acting as the constrictor muscles of the pharynx. Outside the muscular coat is the fibrous coat which binds the pharynx to surrounding structures and holds it in apposition with them. Small mucous glands are found here which are continued into the tissue of the oesophagus.

THE OESOPHAGUS

The oesophagus is a tube which extends from the pharynx to the stomach and serves to carry the food from the former to the latter. Extending from the upper border of the sixth cervical vertebra to the body of the tenth dorsal vertebra, the oesophagus is about ten inches in length, and varies from one-half to one inch in diameter, dependent upon the condition of its walls, whether in a state of contraction or of dilation.

In the oesophagus the same coats are present that exist in the pharynx, namely, the mucous, submucous, muscular and fibrous. The mucous coat is lined with epithelium of the stratified squamous variety placed upon the basement membrane and showing the openings of many oesophageal glands. Immediately under the basement membrane there exists a definite layer of circular muscular fibers which constitute the muscularis mucosa. This muscularis mucosa is not a part of the muscular coat of the oesophagus.

The submucous coat is composed of a fibrous tissue with few elastic fibers present and serves to attach the mucous membrane to the underlying muscular coat. The muscular coat has throughout its entire extent circular fibers and in the lower one-third a layer of longitudinal fibers outside of the circular. In the upper third these fibers are of the striated variety, in the middle a combination of the striated and non-striated, and in the inferior third they are of the plain variety entirely. The outer coat is formed

of connective tissue containing both yellow and white fibers, and it serves to connect the oesophagus to the surrounding structures.

In the oesophagus are found glands of the compound tubular type, the majority of which are of the mucous variety, and they are found throughout the entire extent of the tube, resembling in structure the mucous glands of the mouth and pharynx. Near the gastric end of the oesophagus are found some compound tubular glands resembling in structure the fundus glands of the stomach.

CHAPTER XXXIX

STRUCTURE OF LOWER ALIMENTARY CANAL

STOMACH

The stomach lies in the epigastric and left hypochondriac regions. In shape it varies, although as a rule it is spoken of as pear shaped. Entering the stomach a little to the left of the median line, we have the oesophagus, and the point at which it enters is known as the cardiac orifice. At the lower level and a little to the right of the median line the small intestine has its point of origin. This opening is at the apex of the pear shaped stomach and opens toward the posterior. It is known as the pyloric orifice. The stomach is divided into three descriptive parts, as follows: The cardiac end, that portion of the gastric wall immediately around the cardiac orifice; the pyloric end, that part immediately around the pyloric orifice; and the fundus, which includes the greater portion of the stomach and lies between the cardiac and pyloric areas.

No definite size can be given for the stomach because it is so variable. It admits of wide distension, and when empty its mucous membrane lies in folds which are known as rugæ. Over the entire inner surface of the stomach will be found a honeycomb appearance due to the many small orifices which open on the mucous membrane from the underlying glands. These gland openings are found not only on the rugæ, but in the folds between them, and extending from the cardiac to the pyloric orifices.

Lining the stomach we have a mucous membrane of the simple columnar type, the transition from the squamous columnar type being made at the cardiac orifice. These simple columnar

cells are of the mucous type, and are clear at their proxomal extremities, while at their distal ends are found granules which give to the cell an appearance of opacity. The extent of the clear zone and of the granular zone is dependent upon the activity of the stomach, being clearer during activity and more granular during rest. We have already mentioned the folds into which the wall of the stomach is thrown when empty, and the honeycomb appearance, which is due to the presence of ducts opening from the underlying glands. The mucous cells of the membrane are placed upon a fibrous stroma (tunica propria), in which are imbedded the ducts of the gastric glands.

The submucous coat is a connective tissue layer containing many elastic fibres, and having imbedded in its meshes fats, blood vessels and nerves. The nerves which are found here form the plexus of Meissner, which is also present in this coat of the oesophagus and the intestines.

The muscular coat of the stomach is divided into three layers. The outer is composed of plain longitudinal fibres, the middle coat of plain circular fibres, and the inner coat of plain oblique fibres. These oblique fibres are found only in the stomach, and in the other parts of the alimentary canal only the longitudinal and circular fibres are present. In the stomach the circular fibres are greatly increased in number near the cardiac and pyloric orifices, where they form constrictor muscles, which act as valves. That at the cardiac end of the stomach is known as the cardiac valve, and that at the pyloric is known as the pyloric valve. The latter, however, is stronger and more active than the former. Interspersed between the muscular fibres of the muscular coat are many nerve fibres, which are analogous with, although not as distinctly arranged, as the plexus of Auerbach in the intestine.

The serous coat is merely a continuation of the peritoneum over the muscular coat.

The glands of the stomach may be divided into two divisions; the fundus or peptic glands and the pyloric glands, which are

located in the immediate region of the pyloric orifice of the stomach. The fundus glands are of the simple tubular type (occasionally they are branched), and several of them open into a single pit. The gland consists of a mouth, a neck, a body and a fundus. It is lined with short columnar cells, which are known as the central cells or peptic cells of the gland. These are known as the central cells, because they line the lumen. Scattered cells also lie against the distal ends of the central cells, which are known as parietal cells, oxyntic or acid forming cells. They do not form a distinct layer around the central cells, but are comparatively few in number. They are darker in color than the central cells, oval in shape and communicate with the lumen of the gland by small intercellular canals.

The pyloric glands are found, as the name indicates, near the pyloric orifice of the stomach. Here the pits into which they empty are much deeper than in the fundus of the stomach, being about twice as long as the glands themselves. Several of the glands empty into a single pit, and are lined with central cells which have at their outer extremities only a very few parietal cells.

The pyloric glands are not the only glands which are found in the pyloric end of the stomach. Here also are found small glands resembling in structure the intestinal glands of Lieberkühn. It should not be supposed that there is a distinct line of demarcation between the fundus and pyloric glands, but rather they intermingle for a short distance.

SMALL INTESTINE

The small intestine extends from the pyloric end of the stomach to the illeo-caecal valve, the point of junction of it with the large intestine. About twenty-one feet in length, it is variable in its diameter, being in the duodenum as much as two inches and at the termination in the caecum about one inch. It lies in coils in the middle and lower abdominal region, surrounded at the top and sides by the large gut. The small intestine is divided into

three divisions which are known as the duodenum, jejunum and ileum, the coats of which are continuous with one another. The duodenum is the first section and is about ten to twelve inches in length; continuous with it is the jejunum, which is approximately eight feet in length and serves to convey the bolus of food from the duodenum to the ileum. The ileum is about twelve feet in length and conveys the food bolus from the jejunum to the caecum and is narrower than either of the other divisions of the small intestine.

Characteristic features of the small intestine are the valvulae conniventes and the villi. The former really replace the rugae of the stomach, which it will be remembered are the rough, uneven furrows and folds with which its inner surface is marked. Here in the small intestine, instead of the folds being arranged in no definite order, they are found to be approximately parallel, extending as circular folds part way around the lumen and involving in their structure the submucous membrane as well as the mucous lining. The villi are minute projections from the mucous membrane into the lumen of the gland, and are of different shapes in different parts of the small intestine. In the upper part, or jejunum, they are leaf shaped, in the middle part they are rounded, and in the lower part they are club shaped. It can readily be seen that the appearance of the inner lining in the small intestine would be a great deal different than that of the stomach, because in the former we have many projections in the form of villi, while in the latter the surface is covered with pits and depressions.

There are in the description of the mucous membrane three structures which may be mentioned; the epithelial lining, stroma and muscularis mucosa. The type of lining epithelium is continuous with that of the stomach and is of the simple columnar variety. There are two kinds of cells in the epithelial lining of the small intestine known as the goblet and columnar cells. The goblet cells here are the same as those found in any other mucous lining, but the columnar cells are different than elsewhere and

somewhat peculiar. On the free border of the columnar cells there appears a dark strip, which together with the same substance in the adjoining cells, forms a continuous border cuticle just next to the lumen of the tube. The nucleus of each cell is oval in shape and found usually near the base or in the center of the cytoplasm.

The goblet cells fill the free extremity with mucus globules until practically the entire cell is so filled and the nucleus is pushed up against the base. At this time the mucus globules are discharged from the cell in a mass, and together with the mucus expelled from all the other goblet cells form the mucus secretion of the membrane. Whether the cell again fills with mucus and expells the second mass to the surface, or whether it dies and is replaced by another cell, is a question which is not at this time fully determined. Neither do investigators agree as to the classification of this peculiar goblet cell, some claiming that it is an independent cell entirely distinct from any other cell, while others hold that it is merely a special kind of columnar epithelial cell.

Replacing cells are, as the name implies, small, undeveloped cells, located usually between the bases of the epithelial cells and the stroma or between the cells. In addition to the replacing cells there are small spherical cells located usually between the columnar cells and sometimes within them, and these are known as migratory leucocytes, and it is claimed that they are leucocytes in the course of development. All these cells just described rest upon the fibrous stroma and interspersed in this tissue are a few muscle fibers which constitute the muscularis mucosa.

The submucous membrane is a continuation of that found in the stomach and consists of connective tissue, supporting and holding in situ the surrounding softer parts. In this coat is the plexus of Meissner from which are derived nerve fibers supplying the mucous membrane, muscularis mucosa and the submucous membrane.

The muscular coat consists of a continuation of the circular

and the longitudinal coats of the stomach. The inner layer is circular and the outer is longitudinal and both are composed of the smooth muscle fibers. Between these two layers is a thin membrane of separating connective tissue which divides the one from the other, and in it is found the nerve plexus known as the Plexus of Auerbach, which supplies both muscular layers, and from which are sent in communicating fibers which join with the plexus of Meissner.

The serous coat is a continuation of that of the stomach, and is derived from the peritoneum.

The villi of the small intestine are merely small papillary projections from the surface of the mucous membrane, and in the center of which we find the blind dilated extremity of a lacteal vessel. This lacteal vessel finally empties into the thoracic duct, or the receptaculum chyli, and the lacteal fluid is thus carried to the blood stream, from whence it is distributed to all parts of the body. The stroma upon which the epithelial lining rests, is projected toward the surface, and here it is found that the fibrous tissue of which the stroma is formed, changes, at least in part to a retiform tissue the interspaces of which are filled with lymphocytes. Within this stroma is the central tube or the termination of the lacteal vessel, which is lined with flattened cells.

The crypts of Lieberkühn are simple tubular glands found throughout the small intestine, having their openings between the villi. They are lined with an epithelium continuous with that of the surface lining, and these cells are clear with the exception of those near the end of the tube. Here they show a granulation and are known as the cells of Paneth.

Filling in the space between the tubes of these glands is the stroma, consisting of fibrous tissue with a few lymphocytes. Occasionally these lymphocytes are grouped to form a small mass, or lymph nodule, and when this occurs it is known as a solitary follicle.

Peyer's patches are groups of solitary follicles, which al-

though their bases, which project into the submucosa, and their apices, which project toward the lumen of the intestine, are separated, are confluent at the center of their bodies. About seventy in number in each patch, they are not covered over their apices with the stroma, but only the epithelial cells intervene between them and the lumen of the canal. Villi are absent over the Peyer's patch, so that they are given the appearance of being smooth, rounded eminences.

Brunner's glands are found in the small intestines, especially near the pylorus in the duodenum. Some of them extend into the pylorus, while some of the pyloric glands extend down into the duodenum for a short distance. They are lined with granular simple columnar epithelial cells, and their openings are upon the surface between the villi, or in some cases in the tube of a crypt of Lieberkühn.

THE LARGE INTESTINE

This is the name applied to the intestine extending from the termination of the ileum to the anal canal. It is about five feet in length, and is greatest in its diameter at its beginning, where it measures about three inches; from this point to the entrance into the rectum it gradually decreases in diameter to only one and one-half inches. It is held in a more fixed position than the small intestines, has attached to its outer coat small sacculations of fat known as appendices epiploicae, and possess taeniae coli. The large gut also is sacculated in form, while the small is smooth. This sacculation is the result of the walls of the large intestine being drawn together longitudinally by the taeniae. The taeniae are three muscular bands extending from the beginning to the termination of the large canal, and are about equal distances from one another. They are formed by continuations of the longitudinal coat of muscular fibers found in the small intestine, and take the place of this layer in the large tube.

The large intestine is divided into three parts, the caecum, the colon and the rectum. The caecum is a wide dilated pouch

about three inches in diameter and two and one-half inches in length, although these dimensions may vary a great deal. The ileum does not open into the lower end of it, but at the side almost half way between the base and the beginning of the colon. Here the entrance is made through a slit in the wall formed by two folds of membrane, extending over and almost closing the opening. Attached to the caecum is a blind projection known as the vermiform appendix, which has practically the same structure in its wall as is present in the caecum.

The colon is divided into several subdivisions, known as the ascending colon, the hepatic flexure, the transverse colon, the splenic flexure, the descending colon and the sigmoid or pelvic flexure. The ascending colon extends from the apex of the caecum toward the superior on the right side, lying to the right of the coiled up small intestine until it reaches the under surface of the right lobe of the liver, where it describes a quarter turn to the left, thus forming the hepatic flexure. From here the transverse colon progresses to the left across the epigastric region and into the left hypochondriac region, above the coils of the small intestine, and after approaching close to the left abdominal wall arches toward the inferior, forming the splenic flexure. Now the colon is known as the descending colon and extends toward the inferior until it reaches the inferior border of the kidney, when it arches toward the median line until the crest of the illium is reached. From here it is known as the sigmoid flexure until it reaches the level of the third sacral segment where it terminates in the rectum.

The rectum is the third division of the large intestine and extends from the termination of the sigmoid flexure to the internal sphincter of the anal canal. It is from this dilated pouch that the fecal material is expelled to the external.

In the large intestine we have the same four coats for description as are present in the small intestine; namely, the mucous, submucous, muscular and serous. In the mucous membrane there

do not appear the pits which characterize this membrane in the stomach, nor the villi which are found in the small intestine, so that here the lining is comparatively smooth. The cells lining the lumen are of the simple columnar type, but do not display mucous cells in as great an abundance as do those of the small intestines and are not so broad as the type in the latter case. Thin and narrow they contain small nuclei and rest upon a fibrous stroma which is not so apparent as in the small intestine.

The submucous coat is a continuation of the same layer in the small intestine, and has practically the same structure. Placed in this coat are scattered lymph nodes, although they are seldom found in groups as in the lower end of the small intestine. In this submucous layer we find dense plexuses of blood vessels as well as the nerve plexus of Meissner, which is continuous with the same mass in the small intestines.

The muscular coat is found just outside the submucous coat and consists in bulk chiefly of circular fibers. It is a continuation of the circular coat of the small intestine and the continuation of the longitudinal fibers from the small intestine is here in form of bands of fibers called taeniae.

The serous covering forms the fourth coat and is merely a projection from the peritoneum of a single layer of connective tissue lined by a simple layer of mesothelium.

Numerous crypts of Lieberkühn are found in the wall of the large intestine, extending almost through the mucous membrane stroma. They are of the simple tubular variety, but their tubes are longer than those in the small intestine. While there are few mucous goblet cells in the lining membrane of the large canal, the cells which extend down into and line the glands here present have many of these cells. In other respects the cells of the glands are very much the same as those of the rest of the epithelium in this region.

Several marked differences occur in the structure of the rectal wall as distinguished from the structure of the colon wall. In the rectum the mucous membrane is thicker and the glands of

Lieberkühn are longer at the upper portion of this tube than those found in the colon. At the lower end of the tube there are no crypts at all. The taeniae which are characteristic of the colon are absent in the wall of the rectum, but are replaced by a thick, continuous muscular layer of longitudinal fibers. At the lower end of the rectum the epithelial lining changes from a simple columnar to a stratified squamous type and at the anus this stratified type changes to the characteristic stratified epithelium of the skin.

CHAPTER XL

SALIVARY GLANDS AND PANCREAS

The salivary glands are six in number, placed in pairs, one on each side of the median line. The parotid is the largest of the three, the submaxillary is next in size and the sublingual the smallest.

The parotid gland is the largest, as we have stated, weighing from half an ounce to an ounce. It is located just anterior and inferior to the external ear, and in some cases found to have accessory masses of parotid tissue. When this occurs the accessory mass is drained by a duct which empties into the main duct of the parotid, known as the duct of Stenson. This is a duct having its origin by the joining of small tubes, and after progressing toward the anterior about two inches it empties into the mouth from the body of the cheek by an opening just opposite the second molar tooth in the upper jaw.

The submaxillary gland is situated in the floor of the mouth at the side of the median line, and lies in the submaxillary fossa on the inner side of the inferior maxillary. This gland weighs about eight grammes and is drained by a duct known as Wharton's duct, which after having its origin in the substance of the gland by small radicals, proceeds to the superior and empties on a small papilla at the side of the fraenum of the tongue. Each gland is thus drained into the oral cavity by a duct emptying on the side upon which it lies.

The sublingual gland is located also in the floor of the mouth, but is further toward the anterior than the submaxillary and lies in the depression of the sublingual fossa. Its excretory ducts

are made up in very much the same manner as those of the parotid and the submaxillary except that while the other two are drained by single ducts from each gland, many ducts are found draining the sublingual, each one of which empties by a separate opening on the floor of the mouth. These are known as the ducts of Rivinus. These ducts are from ten to twenty in number and find their opening just posterior to the opening of Wharton's duct, because the latter progresses to the anterior as well as to the superior in passing to the mouth; and even though the body of the gland does lie behind that of the sublingual, the duct empties anterior to those of the sublingual. Sometimes a few of the ducts of Rivinus, instead of emptying individually as single openings, join and proceed not directly to the floor of the mouth, but to the lumen of the duct of Wharton, where the duct formed by them empties and its fluid is thus carried to the oral cavity by the excretory duct of the submaxillary. This duct, when present, is known as the duct of Bartholin.

STRUCTURE OF THE SALIVARY GLANDS

The salivary glands are compound tubular racemose glands, and are surrounded by a capsule of supporting connective tissue, which sends in trabeculae, dividing the gland into lobes, lobules and alveoli. The alveolus is made up of the dilated extremity of a tubule surrounded by secreting cells. These cells are placed upon a base formed by the connective tissue, which divides the one alveolus from the other, and which accommodates the blood vessels and lymphatics which supply the cells with those materials which they will need in their peculiar secretory function.

The cells which line the alveoli in the parotid gland are of the serous type, while those of the sublingual and submaxillary are mixed, being some serous and some mucous. Thus we have both serous alveoli and mucous alveoli, dependent upon the kind of cells with which they are lined. The mucous cells are spherical or pyramidal in shape and during activity are large and clear, being distended with mucus and having the nucleus of the cell

forced against the distal extremity and flattened against the basement membrane. The serous cells line the serous alveoli and can be distinguished from the mucous because their alveoli are not so large, and instead of presenting a clear, transparent body, they display distinct granules which become more pronounced as activity occurs.

There seems to be no doubt but that the tubules which drain the alveoli are lined with secreting cells also, which pour their secretion directly into their lumen, from whence it is carried to the external. These cells in the tubules are little more than pavement cells at the time the tubule leaves the alveolus, but as it progresses and becomes larger the cells with which it is lined also become larger. The tubule which drains a single alveolus is known as a terminal secreting tubule, these tubules uniting to form the intralobular ducts which in turn join to form the interlobular ducts. These latter ducts, as the name implies, lie between the lobules and in the connective tissue trabeculae which separate them. These intralobular ducts join with one another and form interlobular ducts and these, by uniting, form the main excretory duct of the gland.

The blood vessels which supply the salivary glands pass into the substance through the trabeculae and here they break up into radicles and capillaries from which the materials are taken up that are to be used in forming the secretion. The lymphatics of the salivary glands have their origin around the capillaries of the basement membrane and drain the entire substance of the gland.

PANCREAS

The pancreas is placed in the abdominal cavity along the posterior wall lying in the epigastric and the left hypochondriac regions. It is about five inches in length, about one and one-half inches in width and one inch in thickness, and weighs from two to four ounces. It is shaped similar to the tongue, having a large dilated right extremity which is known as the head. This large end of the pancreas lies in the curve of the duodenum. Extend-

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ing toward the left from the head is a constricted part, which lies just in front of the portal vein, and is known as the neck. It serves to connect the head on the right with a long, narrow projection, which extends into the left hypochondriac region. This projection is called the body and gradually tapers down to a termination at the left which is known as the tail.

The pancreas, because of its resemblance to the salivary glands, is often spoken of as the abdominal salivary gland. Its histology, however, is more complicated than that of the salivary glands and in composition it seems to show a looser, more friable texture. It is surrounded by an incomplete capsule of areolar tissue which sends in trabeculae, dividing the organ into lobules and these are subdivided, as are the lobules of the salivary glands, into alveoli.

Draining the pancreas we have a duct extending from the tail of the organ through its tissue toward the right and emitting from the head whence it progresses to its termination in the wall of the duodenum, after having first joined with the common bile duct, with which it terminates. The pancreatic duct enters the duodenum about four inches below the pyloric valve. Sometimes there is given off from the pancreatic duct (duct of Wirsung) another accessory duct, which leaves the main duct during the passage of the latter through the neck of the pancreas and passes independently to its point of termination about one inch above the opening of the common bile and pancreatic ducts. It is not a drainage tube for masses of pancreatic tissue which are sometimes present (known as accessory pancreas), for these are drained by a tube which passes into the duct of Wirsung, but rather is an accessory duct to the duct of Wirsung, helping it to carry away the secretion. It is called the duct of Santorini.

Given off from the duct of Wirsung during its passage through the pancreatic tissue are small ducts which break up into radicles, each one of which supplies a lobule of the organ, and are known as intralobular ducts. From the intralobular ducts are given off small radicles which enter the alveoli and terminate here

in small dilated extremities. These are known as terminal ducts and grouped around them and their dilated extremities are masses of cells, the secreting units of the gland. Lining the tubes and the lumen of the sacculations at their extremities are conical secreting cells which present different appearances at different times during the activity of the digestive tract and the resting period of this organ. When the pancreas is at rest (when there is no food present to undergo digestion from the pancreatic secretions) the cells show two distinct zones; an outer clear zone, and an inner granular zone, this latter being produced by the presence here of zymogen granules. When intestinal digestion first begins the cells of the pancreas become less granular and the clear zone occupies practically the entire extent of the cell, but after digestion has taken place for a short time, and is still continuing, the granular zone predominates and it in turn fills most of the space in the cell.

Other than these granular cells there exist cells which do not change as intestinal digestion occurs, but which rather perform the purpose of supporting the surrounding secreting units. They are placed upon the basement membrane as are the latter, and extend from here to the lumen of the tubule of the alveolus which they line. The cells of Langerhans are small cells differing from the secreting cells and arranged, not as the secreting cells, around tubules, but rather in isolated masses, which are sometimes spoken of as island masses. There are no drainage tubules in these masses and the cells do not show a granulation, as do the tubular cells. However, these cells are very richly supplied with capillaries and from the fact that they are not drained by ducts, it is generally conceded that they must form a secretion which is poured into the blood stream. Because of the manner in which this secretion is carried away it is called an internal secretion, but practically nothing is known as to its composition or function.

The basement membrane upon which the cells of the pancreas are supported is of a very loose areolar tissue, supporting the parenchyma and serving as a means of entrance and exit for the

blood vessels, lymphatics and drainage ducts. Here, too, we have brought forcibly to our minds the proof of the existence of an Innate Intelligence, which not only regulates the amount of secretion which must be formed, but also gives to the cells the power to select from the blood and lymph those materials which are needed in its peculiar secretion and changing them into the peculiar secretion of that particular gland. The amount of pancreatic fluid which is secreted depends upon the quantity and quality of food which is present in the intestine to be digested. If of large quantity and containing much fat, Innate becomes aware of this fact by means of impulses carried to the brain over the afferent nerves, and immediately impulses are started to the pancreas, which produce activity of the cells here, and large quantities of pancreatic juice (the principal agent in the splitting of fats) are secreted and pass out through the duct of Wirsung to the intestine. If on the other hand the amount of fat in the food is not great, Innate also becomes aware of this fact through impulses received over the afferent nerves and as a result few secretory impulses are sent down the efferent nerves to the pancreatic secreting cells.

CHAPTER XLI

LIVER

The liver is the largest gland in the body, of a dark reddish color, and weighs from forty to sixty ounces. Slightly larger in the male than in the female, it is found to lie in the right hypochondriac, the epigastric and part of the left hypochondriac regions. In shape it is wedge-shaped, the apex of the wedge being toward the left and the base toward the right. It lies immediately beneath the diaphragm, with which it is in contact on its superior surface. The dimensions of the liver are; lateral diameter 8 to 9 inches, vertical diameter at the right side 6 to 7 inches, antero-posterior diameter at the right side 4 to 5 inches.

The liver consists of five lobes, which are the right, the left, the quadrate, the Spigelian and the caudat lobes. These lobes are separated from one another by five fissures, known as the umbilical fissure, ductus venosus fissure, gall bladder fissure, post cava fissure and the transverse fissure, which are so named because of the fact that they form a depression in which lie organs of the same name as those names applied to them. This is true with the exception of the transverse fissure, which is found separating the quadrate from the spigelian lobe, and through which most of the principal vessels entering and leaving the liver pass.

STRUCTURE OF THE LIVER

Surrounding the substance of the liver we have a double layer of enveloping membrane. The outer division of this capsule is of serous tissue and derived from the peritoneum, while the inner one is of fibrous areolar tissue and is much stronger and firmer than the former. The serous membrane does not entirely

surround the liver, but the fibrous capsule does, and it is known as the capsule of Glisson. At the transverse fissure the capsule is reflected inward along the course of the great vessels which enter and leave here, and line the canal in which they lie, for a short distance, into the liver substance. This canal is called the portal canal. It enters the substance of the liver at the transverse fissure and progresses into it, branching and rebranching for a short time until the lumen becomes too small to accommodate the vessels which lie in it and then it terminates. In the portal canal lie four important vessels: these are the portal vein, the hepatic artery, the hepatic duct and the lymphatics. This portal canal is lined by the extension inward of the capsule of Glisson, and in considering the capsule of Glisson we should not think of it as a surrounding membrane of the liver alone, but also as a lining of the portal canal.

Extending inward from the capsule of the liver are projections of areolar tissue, which in man are very incomplete. These layers of connective tissue serve to separate the lobules of the liver from one another, to some degree, but the principal factor in distinguishing between them is the presence of vascular plexuses between them. These lobules are the subdivisions of the lobes and form the entire parenchyma of the liver substance. They vary from one-tenth to one-twentieth of an inch in diameter and may be discovered either by making a cross section or viewing the surface.

In describing a lobule, possibly the nicest comparison would be with a blackberry. Here we have the berry representing the body of the lobule, the seedlings representing the cells forming the lobule and the central core of the berry representing the central vein of the lobule which carries the blood away from it. Keeping this comparison in mind we may say that the lobule consists of a mass of cells, the entire mass being shaped like a blackberry, and in its center a small venule known as the central vein, and emptying at the base of the lobule. Intervening between this central vein and the surface of the lobule are masses of secreting

cells which will be considered in detail later. Having stated that the central vein of the lobule empties at its base, we must designate a vessel into which it empties. The sublobular veins are many, and lie in the substance of the liver as small radicals of the hepatic veins which drain the blood from the liver. Against the walls of these sublobular veins we find abutting the bases of countless lobules, and from the center of each of the bases is seen emitting a minute venous radical, the central vein of the lobule. If a longitudinal section of one of these sublobular veins should be made it would disclose irregularly shaped lobules, the bases of which form the wall of the vein.

The hepatic artery is derived from the coeliac axis of the abdominal aorta and immediately progresses to the right where it enters the liver at the transverse fissure. In the portal canal it lies in company with the portal vein, hepatic duct and the lymphatics. The hepatic artery gives off vaginal branches which proceed to and supply the walls of the blood vessels of the liver and the small amount of connective tissue which separates the lobules from one another. It also sends out capsular branches which, as the name implies, proceed to and supply the enveloping membrane of the gland. The third set of branches given off from the hepatic artery are the interlobular, which as the name implies, are found between the lobules. Here the branches, together with the branches of the portal vein form the interlobular plexuses from which are given off capillaries that enter the lobule, lie between the cells for a short distance and finally terminate in the central vein of the lobule. The hepatic artery, proceeding as it does from the aorta, carries arterial blood and supplies the tissues of the liver with oxygen.

The portal vein is, in many respects, like an artery. It branches like an artery and not like a vein, and its blood finally reaches a set of capillaries as does the blood of the arteries. The blood found in the portal vein, however, is not arterial blood, being derived from the uniting of the superior and inferior

mesenteric, gastric, splenic and cystic veins. These veins drain the great part of the abdominal viscera, and this venous blood which has been through one set of capillaries, passes into the liver by means of the portal vein which branches at the same points as does the hepatic artery and finally forms with it the interlobular plexus. We have stated that from this plexus are derived arterial capillaries, which supply the cells of the lobule with oxygen, and we may properly call the capillaries which arise from these small veins of the interlobular plexus, venous capillaries, because they carry carbonated blood throughout their entire course. These capillaries which arise from the radicles of the portal vein in the interlobular plexus also empty into the central vein of the lobule, so that all the blood carried to the liver by either the hepatic artery or the portal vein, which is not used by the liver cells, is carried away by the hepatic veins.

The hepatic veins are three in number, leaving the substance of the liver from the right side, center and left side, and emptying into the inferior vena cava. These hepatic veins are the vessels which drain the blood from the liver and have their beginning in the central veins of the lobules. These central veins all flow into a larger vein known as the sublobular, and these in turn unite and reunite to form the three large hepatic veins. Upon making a cross section of the liver the hepatic veins may be distinguished from the portal in that the former stands open upon section while the latter collapses. This is for the reason that the hepatic vein has its wall attached to the wall of the canal through which it is passing by means of cementing material, while the portal vein, lying in company with the other four vessels is not so supported, and hence collapses. Another distinguishing feature is the presence of the accompanying vessels with the portal vein and their nonexistence in association with the hepatic vein.

The terminal radicals of the hepatic ducts begin between the cells of the lobules and progress from here to an interlobular plexus between the lobules formed of hepatic duct radicals. There

is no wall limiting these intercellular tubes except the liver cells themselves, between which the terminal radicals have their origin and from whence they emit to the interlobular plexus. This plexus is drained by larger ducts and they join and rejoin at the points where the hepatic artery and portal vein and their radicals divide. In this way we have one hepatic duct always in company with one hepatic artery and one portal vein.

The lymphatics of the liver have their origin between the cells in very much the same way as do the hepatic ducts, namely, between the cells and around the outer walls of the capillaries. Here the lymph finds its way out from the vascular stream and enters the perivascular lymph spaces, which in turn supply the small lymphatic tubes that pass out from the lobule and form the interlobular plexus. These plexuses are drained by larger lymphatics which unite and reunite to form the main lymph vessels of the liver and leave its substance following the same general course as do the small radicals of the hepatic ducts.

CHAPTER XLII

MECHANICS OF DIGESTION

The digestion of foods is partly mechanical, partly chemical and partly a mental process. It is true that the chemistry of the digestive process is more complicated, but it is not necessarily more important. The mechanical activity is very important in that it is by this process that the food is started in its journey along the alimentary canal, and the means by which this journey is continued until the fecal matter is finally eliminated from the body at the anus.

MASTICATION

Mastication is the mechanical process which takes place in the mouth and serves to break the food into small particles. Because of the peculiar articulation of the mandible with the skull there may be many positions assumed by it which best serve in this mechanical process. The muscles which serve to raise the mandible are the internal pterygoids, the massaters and the temporals, while those which serve to lower it are the mylohyoid, the geniohyoid and the digastric. The external pterygoids serve to move the mandible from side to side, and these when acting independently of one another produce the peculiar grinding action which effects especially the food between the molar teeth. If the two pterygoids act in unison it produces a forward projection of the mandible, and the contraction of the temporal muscles alone cause a retraction. Aiding these muscles which control the mandible, we have also the action of the tongue, lips and cheeks in changing the position of food in the mouth, keeping it between the teeth, where it may be broken down, and finally placing it in a position in the mouth, where it is ready to be swallowed.

DEGLUTITION

Deglutition is the act of swallowing and is in part voluntary educated and in part voluntary Innate. For the sake of convenience in description it is divided into three stages, according to the structures through which it successively passes. The first stage is that occupied in the mouth; the second stage, in the pharynx, and the third stage, in the oesophagus.

The first stage of deglutition is accomplished as has been said in the mouth. The food, after being thoroughly masticated and insalivated, is ready to be passed on to the stomach, through the pharynx and oesophagus from the mouth. In the mouth the food is gathered in a mass on the dorsum of the tongue, and this flexible organ by pressing on the hard palate, beginning the pressure at the tip, and continuing it from here toward the posterior, increases the pressure behind the food, thus forcing it back toward the isthmus of the fauces. At the time the food passes the isthmus and enters the pharynx, the first stage of deglutition is completed and the second stage has begun. The first stage of swallowing may be considered partly educated and partly Innate. Undoubtedly the first part is educated because during this time the food may be expelled, and is entirely under the control of the educated intelligence. After the first part of the first stage is over, however, it is doubtful that the act is an educated one, but rather is controlled by Innate Intelligence.

The passing of the bolus of food from the fauces to the entrance into the oesophagus must of necessity be rapid, because the pharynx is an air passage as well as a passage for food, and this air tract cannot be occluded for any appreciable length of time without producing undue discomfort. This is the second stage and would appear upon first consideration to be a very simple act. It must be remembered, however, that there are seven openings into and from the pharynx, and while the bolus enters through one of these and leaves by another, the other five must be so controlled that the food will not enter them. As the pillars

of the fauces contract they tend to force the food backward into the pharynx, but we have located just above the point of entrance of the isthmus of the fauces, the two posterior nares and the pharyngeal openings of the eustacheon tubes. In order that the bolus may not enter these openings, the soft palate is drawn backward and against the posterior wall of the pharynx, thus entirely covering them. At this same time the tongue is drawn forward as is the larynx, thus increasing the size of the tube into which the bolus is to pass. At this time there is a compression behind the food assisting in its onward propulsion. The food has now entered the pharynx, and the constrictor muscles of this organ contract above it and relax below it, thus forcing the food toward the lower end of the pharnyx. There is, however, another opening past which the food must travel before entering the oesophagus and it is essential that no particles may find their way into this opening, for in so doing they would reach the air passages leading to the lungs. If here the food bolus was of sufficent size the air would be entirely cut off from the air sacs or a part of them, or if of smaller size would lodge in the mucous membrane and in short time give rise to an inflammatory condition. To prevent this occurrence then, the lateral crico-arytenoid muscles and the arytenoideus muscles contract, thus drawing the vocal cords tightly together and occluding the opening. Further than this the larynx is drawn upward and forward, thus out of the path of the food. Whether the epiglottis closes or not is a matter of dispute, but it is sufficient to say that the other actions are competent to prevent any food from passing into the larynx, and if the epiglottis does descend as a covering it is merely a further precautionary measure. Occasionally small food particles do find their way into the larynx, through an incompetence of the laryngeal muscles, but when this does occur there immediately ensues a violent coughing, whereby the foreign substance is expelled. This, of course, providing the material is not too large, or becomes stuck to the wall of the air passage.

The third stage of deglutition is that produced by the passage of the food from the lower end of the pharynx to the cardiac sphincter muscle present at the point of entrance of the oesophagus into the stomach. The action which is present and the rapidity of this act depends largely upon the fluidity of the food passing along the canal. Recent investigations have shown that water or other fluids are passed very rapidly along the oesophagus. After the food reaches the lower end of the oesophagus it proceeds more slowly, and only enters the stomach upon the relaxing of the cardiac sphincter. If the food is semi-fluid it proceeds more slowly and if very solid in character it is carried entirely by the peristaltic activity of the pharynx and oesophagus.

GASTRIC MOVEMENTS

The stomach is one of the most remarkable organs in the entire body in that it allows the individual to eat rapidly and after the food has been consumed to pass it on slowly into the long alimentary canal, that each part may be thoroughly digested before it is expelled from the body. In brief the stomach is nothing more than a dilated sac along the course of the alimentary canal which serves as a reservoir to hold and partly digest the food before it is allowed to pass further. If it were not for its presence we could only take in food gradually to gain the best results in the digestive process.

In the study of the stomach the investigator may adopt any one of several methods. The stomach may be exposed by a section of the abdominal wall, auscultation may be employed for the purpose of listening to the splashing and gurgling sounds with which digestion is accompanied, and of late years the x-ray has proven itself of inestimable value in its study. By the use of this latter apparatus the position of a bismuth meal may be observed and the activity of not only the stomach, but other parts of the canal may be noted.

Observers agree that the principal activity occurs at the pyloric end of the stomach, while the cardiac end is relatively in-

active. There are waves of contraction which originate in the fundus and progress from there to the pyloric valve, increasing in strength as they approach the pylorus. These waves in man occur about every twenty seconds and consume about twenty seconds in their passage. It should be remembered that the stomach is cut off from the rest of the alimentary canal by the cardiac and pyloric valves and these are kept closed except upon the entrance or exit of food. Upon examination of the stomach it is found that the foods taken one after the other form themselves into distinct layers. For example, a certain quantity of food when ingested into an empty stomach dilates and fills this organ. If another food which may be readily distinguished from the former is taken, it enters at the cardiac orifice, and forcing the first food out against the convex curvature, takes up its position in a mass about the cardiac orifice. Assuming that a third substance is taken, it will force out the second, and in turn take up its position near the cardiac valve. These different kinds of foods will form definite and distinct layers, which will be more easily distinguished if the food is not of too fluid a consistency. After entering the stomach in this manner the food then begins to undergo a maceration and churning at the same time that it is being forced toward the pyloric valve and is being acidified.

"ACID CONTROL" OF PYLORUS

The "acid control" of the pylorus is an expression used to indicate the manner in which it is thought the pyloric valve responds to chemical vibrations. As different sections of the bolus are acidified and passed on toward the pylorus, and finally are pressed against the valve itself, the acidity produces vibrations on the afferent nerves having their peripheries here and these afferent nerves convey impressions to the brain where an interpretation is made. As the result of this interpretation, efferent inhibitory impulses are sent down to the pyloric valve, causing it to relax. The food now passes on through the valve, and upon reaching the duodenal side, again acts on the peripheries of afferent nerves

ending here. The acidity produces a vibration at the terminations of these afferent nerves, which convey impressions to the brain, where after an interpretation is made, impulses are sent to the pylorus along motor nerves, and as a result the valve is closed.

It can be readily seen that some foods are more easily acidified than others, and these would pass on into the duodenum more rapidly. It can also be seen that, due to the comparative inactivity of the cardiac end and the activity of the pyloric end, the foods will not all become acidified at the same time, nor would they all be brought to the pyloric valve at the same time. In general it may be said that the bolus of food undergoes gastric digestion and becomes chyme in about three hours and by that time is all emptied into the duodenum.

Parts of it, however, begin to leave in approximately thirty minutes. These periods, however, are subject to wide variations, depending largely upon the size of the meal, its chemical consistency and fluidity.

MOVEMENTS OF SMALL INTESTINE

After the food has passed from the stomach and reached the duodenum through the pylorus it starts on a journey through the small intestine, a distance of some twenty-one feet. After reaching the duodenum, the bolus very soon is neutralized by the alkaline secretions of the small intestine, so that it fails to produce vibrations for afferent impulses, which in turn produce motor impulses and close the valve.

In the small intestine there are two mechanical actions which are important; peristalsis and segmentation.

Peristalsis is the activity which is produced by the alternate contraction and relaxation of the circular muscle fibers along the course of the intestine. This occurs in a wave progressing from the pyloric to the ileocecal valve, and whether there is any action of the longitudinal fibers which assists in this wave is not definitely determined. It is the purpose of this peristaltic action to propel the food bolus along the canal, and that this may be accom-

plished, it is necessary that the pressure behind the mass be greater than that ahead of it. Remembering that the food bolus is largely liquid (about 90 per cent water at the ileocecal valve) it must obey the laws controlling liquids, and their movements in tubes. The pressure behind the food bolus is made greater by the contraction of the circular muscle fibers and the pressure ahead of the bolus is made less by the relaxation of the fibers. Along the course of the gut, this relaxation wave passes ahead of the contraction wave, and each wave carries with it a certain amount of food.

The term retroperistalsis is used to indicate a backward peristaltic action, progressing from the ileocecal end of the intestine toward the gastric end. Whether this occurs in the lower end of the small intestine is not definitely determined, but we do know that food elements taken into the duodenum are sometimes expelled through the pyloric valve into the stomach and to the external through the oesophagus, pharynx and mouth. This intestinal vomiting is unusual, but does occur at times.

Segmentation is the act whereby the food is broken up into segments by a local violent contraction of the circular fibers at certain intervals. The bolus may thus be broken into eight separate and distinct masses, at the center of each one occurring another contraction which presses two adjacent masses together. In this manner the food is churned and thoroughly mixed with the intestinal juices. Not only is this accomplished, but the segmentation serves to bring the various particles of the food in closer relationship with the intestinal wall and facilitate absorption.

MOVEMENTS OF LARGE INTESTINE

The movements in the large intestine are usually considered to be similar to those in the small intestine except that they proceed at less frequent intervals. Late investigations with the x-ray, however, seem to point to the fact that in the ascending and part of the transverse colon, a retroperistalsis occurs even more fre-

quently than the normal peristalsis. There is, however, at the point of entrance of the ileum into the caecum, a valve which prevents regurgitation of the food into the small intestine. There is also a sphincter muscle which serves to assist the valve. This retroperistalsis serves to thoroughly mix the food and brings its various particles time and again into direct contact with the wall that absorption may take place more readily. At the time the bolus enters the large intestine it consists of about 90 per cent water, while at the time it is emitted as fecal material it consists of about 75 per cent water. The food remains some time in the large intestine to facilitate this absorption of water. It must not be understood that retroperistalsis is the only type which occurs in the beginning of the large intestine. Normal forward peristalsis occurs at intervals after retroperistalsis has occurred for some time and this action serves to convey the food onward along the large canal. In the last part of the transverse colon and in the large gut from here down it is not thought that retroperistalsis occurs at all, but that the bolus is passed onward very slowly toward the rectum. It takes about two hours for the bolus to traverse the ascending colon, two and one-half hours for it to traverse the transverse colon, two hours to traverse the descending colon and six hours to traverse the pelvic colon. In all an average time consumed in the passage of the food through the alimentary canal from the time it is taken until it is expelled is from eighteen to twenty hours, but upon these computations a variation may be expected, due to the quality and quantity of food.

VOMITING

Vomiting is the term applied to the act of violently ejecting food from the stomach to the external through the oesophagus, pharynx, and mouth. There has been much argument upon the activity of the stomach during vomiting and many experiments have been made to prove or disprove that the stomach is undergoing muscular contraction during this act. Thus far observa-

tions have shown that the strength of the abdominal muscles in contracting and the assistance of the thorax are sufficient to expel the contents of the stomach without any assistance from this latter organ. On the other hand some claim that the pyloric end of the stomach contracts violently, thus tending to decrease the size of the stomach and by so doing increase the pressure. The fact that the force of the abdominal muscles and the thoracic muscles is sufficient to expel the food is not proof that the stomach does not contract, but only that it it is not imperative that it should do so. There is no evidence of a retroperistaltic activity in the oesophagus, but it is thought that at the time the abdominal muscles contract and compress the stomach against the diaphragm, the diaphragm tends to descend while the glottis is kept closed. This decreases the pressure in the thorax and the walls of the oesophagus tend to pull outward and thus the lumen of this organ is increased and offers practically no resistance to the ejection of the stomach contents.

DEFECATION

Defecation is the action of expelling fecal matter from the rectum to the external through the anal canal, and is an act partly voluntary and partly involuntary. As soon as a particle of fecal material reaches the rectum it acts as a stimulus, which produces afferent impulses passing to the brain. As a result of interpretations of these impulses, efferent impulses are sent down to the muscular coat of the descending and transverse colon, which produce here a peristaltic action, thus forcing the fecal matter into the rectum. From here, however, it cannot escape, owing to the tonicity of the external and internal sphincter ani. It is only when this involuntary action is accompanied by a voluntary action that evacuation of the fecal matter is accomplished. The voluntary action is begun by an inspiration which serves to depress the diaphragm, and the diaphragm is then held down by the closure of the glottis. The abdominal muscles now contract and compress all the abdominal viscera, and at the same time the

external sphincter ani is relaxed. This voluntary action, assisted by the involuntary peristaltic motion, serves to expel the fecal matter from the anus.

The fact that the peristaltic action occurs in the descending as well as the pelvic colon and rectum, produces a wide variation in the time which is consumed by the food bolus in passing through the alimentary canal. When the bolus reaches the descending colon it has only been in the canal from nine and a half to twelve hours, and the peristaltic action of the colon may carry it downward through the pelvic colon and into the rectum during the act of defecation. Thus, this particular mass of food remains a much shorter period than the average.

CHAPTER XLIII

CHEMISTRY OF DIGESTION

The food in its journey through the alimentary canal undergoes not only the mechanical action of the organs through which it passes, thus becoming thoroughly mixed, but it also undergoes the activity of the various secretory juices which act upon it and serve to break down the compounds of which it is formed into simpler bodies which are capable of being taken up and used in the tissues of the body.

A ferment is an organized micro-organism, which by its reproduction is capable of changing large quantities of substance. The action of such a ferment is hindered by the accumulation of products of disintegration which it produces in the tissue. It is claimed that, inherent in each cell of the organized ferments, is a substance which is capable of breaking down the accumulation products, thus allowing the process of fermentation to go on unhindered until all the accessible material has been broken down. Ferments are often considered as both organized and unorganized substances which have the power of producing changes in large quantities of substance. In this event the definition of a ferment would also include that class of substances known as enzymes. In order to definitely distinguish between a ferment and an enzyme, we will class the former as organized bodies and the latter as unorganized bodies, both of which have actions which are identical. Then an enzyme is an unorganized substance which is capable of producing a change in large quantities of substance.

In the organized substances, or ferments, the activating material passes out from the cells and comes into direct contact with the substances to be acted upon, which are in contact with the cells

themselves. In the other case, that of enzymes, the activating materials are given off from the cells and do not immediately come in contact with the substances to be acted upon, but may pass for some distance, possibly through ducts or tubes, to the substances which they act upon.

It is impossible to determine the exact composition of enzymes, partly because they are secreted in such minute quantities and partly because they are so masked by the presence of proteids that it is impossible to separate them and thus produce them in their pure form. Some investigators claim that the enzymes are proteids, but the consensus of opinion points to the fact that they resemble the proteids in some ways, but should not be classed with them.

A peculiar feature about enzymes is the fact that they produce changes in substances of such greater bulk. Thus rennin (an enzyme of the gastric secretion) is capable of producing coagulation of 700,000 to 800,000 times its quantity of milk. Certain enzymes are affected in their action by the conditions under which they labor. The chemical in which the enzyme works may alter its action, or the temperature under which each labors may alter the activity. The optimum temperature is the term applied to that degree at which each substance acts with the greatest degree of success. Above this optimum temperature the activity is inhibited to a certain degree, decreasing as the temperature increases, until finally a point is reached when the action is completely stopped. Above this temperature a point may be reached wherein the activity of the enzyme is permanently destroyed. Again, as the temperature decreases, the activity of the enzyme decreases until a point is reached where its action is completely stopped.

In the consideration of enzymes it is important to note that after they have acted on a substance and formed a large quantity of their product, their action is decreased and finally stopped. However, if the product of their activity is removed they are then capable of carrying on their work with renewed vigor, equal to

that which they possessed when first secreted. In brief the enzyme is a physiological catalytic agent which is capable of producing marked change in other substances without itself becoming changed.

Sometimes the enzyme is not directly secreted from a cell, but another substance is formed which becomes changed upon coming in contact with another material and thus the true enzyme is formed. Thus trypsin, an enzyme of the pancreas, is preceded by a substance known as trypsinogen, which upon coming in contact with enterokinase changes into the true enzyme trypsin.

There are certain zymolytic groups which are divided according to the substances which they act upon. They are:

Proteolytic enzyme. This is an enzyme, which as the name implies, acts upon fats, converting them into fatty acids and glycerin. An example of this class of enzyme is steapsin, found in the secretion of the pancreas.

Coagulating enzyme. This is an enzyme which has the power of changing soluble proteins into a state of insolubility. An example of this type of enzyme is rennin, found in the gastric juice.

Sugar splitting enzyme. This is an enzyme which has the power of splitting sugars. Such an enzyme is lactase, which has the ability of splitting lactose into glucose and galactose.

Amylolytic enzyme. This is an enzyme, which as the name implies, serves to change amyloses (principally starch) into sugars. An example of this type of enzyme is found in ptyalin, an enzyme of saliva.

Hydrolysis. This is the term applied to indicate the addition of water to a chemical substance, thus changing it into another substance. It is known that this is the change which occurs in the action of the amylolytic enzyme, changing starch to sugar, and it is suspected that it is also true in the proteolytic and other zymolytic actions. At any rate it is an acknowledged fact that water is essential for the activity of all enzymes.

Having prefaced the subject of the chemistry of the digestive system with these remarks it is now necessary to consider the enzymes which are secreted by various glands along the course of the alimentary canal, as well as the substances which they act upon and the products which are formed as a result of their activity.

SALIVARY DIGESTION

Beginning at the anatomical beginning of the alimentary canal we have found here the saliva. This is a substance secreted not only by the salivary glands, but also by the mucous glands located in the mucous lining of the oral cavity. It is a clear viscid fluid with a specific gravity of 1.002 to 1.008 and containing from .5 per cent to 1 per cent solid material. Alkaline in reaction it is secreted in some degree at all times, but especially during ingestion of food. Normally there are about three pints secreted daily, but this of course varies, dependent upon the quantity and quality of food. It is stated that sometimes the saliva is acid in reaction, but it is to be doubted whether this is true of pure saliva. Probably an acid reaction indicates a fermentation of food elements in the mouth.

Upon examination under the microscope it is found that contained in the saliva are epithelial cells and leucocytes, the result undoubtedly of katabolic metabolism. These particles are not considered as a part of saliva because not secreted by the glands, but rather should be classed as foreign substances which are being borne along by the saliva and will in time be eliminated from the body as waste products.

Chemical examination shows the presence of ptyalin, mucin, and proteids in very minute quantities. Also a substance known as potassium sulphocyanate, which is supposed to be the product of protein katabolism, but the origin of which cannot be definitely established.

Of these various substances found in the saliva, undoubtedly ptyalin is the most important from a chemical point of view,

although the fact must not be lost sight of that the saliva as a whole acts in a mechanical way as well as in the chemical sense. Ptyalin is an amylolytic enzyme and thus acts upon starches, changing them into maltose. It resembles the diastatic enzyme, which is found in malt in its action, and so is often spoken of as a diastatic enzyme, but it differs from diastase in that its optimum temperature is 46 degrees C., while that of diastase is about 53 degrees C. The activity of ptyalin is destroyed at about 67 degrees C., but as low as 35 degrees it still acts thoroughly.

The outer coat of starch cells is formed of a substance known as cellulose, which is not acted upon by ptyalin. It is necessary then that the starch within the cell shall become exposed by some means and come into contact with the ptyalin outside. By cooking starchy foods the cellulose capsule is dissolved and the starch on the inside is hydrated, thus becoming not only susceptible to the action of the ptyalin because of the removal of the capsule, but hydrated starch is more easily acted upon than non-hydrated starch.

Ptyalin is alkaline in reaction, and acts best in a neutral substance. If the saliva comes in contact with a free acid, in very minute quantities its action is inhibited and if it comes in contact wth strong acid, its action is entirely stopped.

As to whether or not the food continues to undergo salivary digestion after it reaches the stomach has been a matter of dispute for a long time. It has been maintained that it is essential for this to occur as the food remains in the mouth and oesophagus for only a very short time, insufficient in length to allow the enzyme ptyalin to act thoroughly on the starches. On the other hand it has been argued that very little of the starches were broken down in the mouth and oesophagus, but that most of this action occurred when amylopsin of the pancreas came in contact with the food bolus.

We must concede that the food remains in the mouth and oesophagus scarcely long enough for the food to undergo change

in any great degree. Further we have just stated that the acid in very minute quantities destroys the activity of ptyalin. The juice of the stomach is strongly acid, and upon first thought it would appear that as soon as the food had entered the stomach, these juices would alter the ptyalin to such a degree that it could not act. This would be true of the acid of the stomach were it free acid, but it must be remembered that it is mixed with the proteids of the gastric juice as well as the proteoses and peptones which are the direct result of gastric digestion. Some time must elapse before the action on the proteids has progressed sufficiently to allow any free acid to present itself. Just how long this is, remains very largely a matter of question. It is known that the food begins to leave the stomach about thirty minutes after an ordinary meal has been ingested. We know further that this opening of the pyloric valve is due to the presence of free acid on the gastric side of the pylorus. Certainly then, free acid is not present less than thirty minutes after the first morsel of food in a meal is taken. We know further, that it is approximately three hours before all of an ordinary meal leaves the stomach and this leads to the further important conclusion that all the food bolus is not acidified before this time. This being true, and when we consider the mechanical action of the stomach in its peristaltic waves at the pyloric end, we are led to the belief that those particles of food at the cardiac end of the stomach (the cardiac end lies just below the opening of the oesophagus) are not acidified for at least two or three hours after being taken into the stomach, and thus there is no free acid in this region until that time. If this is true, then the food which is gathered at the cardiac end of the stomach is allowed a period of between two and three hours in which to undergo salivary digestion, as the saliva is constantly being poured down the oesophagus from the mouth. If this argument is founded upon sound reasoning, then the salivary digestion is much more important than has been considered by many authorities in the past.

The importance of saliva as a whole must not be confined to the action of ptyalin. True, this is the principal chemical agent which has to do with salivary digestion, but saliva also has a mechanical office to perform. It serves during mastication to act as a fluid which may be worked in between the particles of food, thus serving to keep them apart and allow for the greater activity of the ptyalin, but also it remains and holds the particles apart in the stomach, thus rendering them more easily digestible by the gastric juices. Saliva also acts as a lubricant, moistening the pharynx and oesophagus as well as the oral cavity. It is efficient in this capacity because of the mucus secreted by the mucous glands, forming a part of it. Saliva is also important in that it is liquid, largely water, and serves as an agent to dissolve soluble substances which come into the mouth. Only soluble substances can be tasted and these only when they are in a state of solution. This explains why, in certain diseases where the saliva is deficient in quantity, there is experienced a difficulty in swallowing and a loss in degree of the sense of taste.

GASTRIC DIGESTION

Gastric juice, when free from saliva and food particles, is a thin, watery fluid with a specific gravity, varying between 1.001 and 1.010. It is found to consist of small quantities of proteins and sodium chloride, of traces of other salts and lactic acid, together with small and varying amounts of hydrochloric acid. Along with the above substances are the three important enzymes, pepsin, rennin and lipase.

The amount of gastric juice is subject to great variation, depending largely upon the kind and amount of food ingested. The glands furnishing this secretion are the fundus and pyloric, described under the structure of the stomach.

Pepsin is considered the most important proteolytic enzyme of gastric juice, breaking down the protein molecule into proteoses and peptones. It acts best in an acid medium of 0.1 to 0.2 per cent strength and is easily destroyed by even very weak alkalies.

Its optimum temperature is 40° C., the enzyme breaking down at 56° C. when mixed with water, capable of withstanding a higher temperature in the dry state. Hydrochloric acid is used to acidify the stomach contents and make action of pepsin possible, but it should not be understood that no other acids could be used, for such as oxalic, lactic and formic produce a medium in which the enzymes work very effectively.

Pepsin is not secreted as such, but rather as pepsinogen, which becomes activated by the presence of hydrochloric acid and transformed into true pepsin. This, as we have stated, acts upon proteins producing proteoses and peptones which become further digested by the action of trypsin.

Rennin or rennet is found in gastric juice and by some authorities is claimed to be a separate and distinct enzyme, while others consider it merely as a part of pepsin. The former view seems more reasonable since such an enzyme is found also in the pancreas and obtained in certain plant life. It has the power of coagulating milk, hence known as the milk curdling enzyme.

An enzyme, lipase, possessing the power of breaking down fats has been described, but this action is largely left to lipase of the intestines. The former is said to act in acid and the latter in alkaline medium.

Hydrochloric acid is classed among the physiologically important substances of the stomach. It is present in quantity varying from a mere trace to 0.6 per cent of the liquid contents. Among some, it is claimed that this acid is the first to enter into effective digestion, forming a combination with the protein molecule. Here the acid is also present in varying amounts from 5 to 15 per cent of the protein weight. It prevents fermentation in the stomach, transforms pepsinogen into pepsin and creates an acid medium for gastric enzymes to work in.

PANCREATIC DIGESTION

After the partially digested food leaves the stomach it comes in contact with other digestive agents in the intestines, which

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composition and prepare it for absorption. The
precedes that in the intestines is only a prepara-
up the particles, which in this simple form
by other digestive enzymes. Thus, in the
intestinal tract the partially digested food is
types of changes by pancreatic ferments.
is completed, likewise is the carbohydrate,
are but slightly changed, are transformed here
substances.

juice consists largely of water with but little
solid elements. No definite amount of this
as normal, as there are many agents and
increase or diminish the flow, yet the
to be about six hundred cubic centimeters.
is pronounced to be a very important agent
flow of this secretion as well as are certain
by experiment that the presence of different
in the upper intestine call forth varying
juice. The most active of these agents is
acid. The presence of any of these agents
impulses in this locality, which impulses are
fibers to the brain where the necessity of
and proper impulses are sent to the
function of secretion. If the flow of the
hindered the amount of secretion will be
seen from the above statement that different
varying amount of secretion.
pancreatic juice is alkaline, and enzymes,
lipase are present.
by the pancreas as such but rather as
changed on coming in contact with an
known as enterokinase, described later.
and hence is classed as a proteolytic
that it acts upon the products of peptic
breaks them down into simpler bodies.

trypsin is capable of breaking down the proteins from the beginning and carry on the cleavage until they are ready for absorption. This enzyme differs from pepsin in that it acts in an alkaline solution, while pepsin acts in an acid solution. It is much more powerful and acts more quickly, and its digestion of fibrin is not preceded by a preliminary swelling as in the stomach, but consists of a process of eating away from the outside, and further it is capable of acting on such substances as elastin which are incapable or at least difficult of digestion in the stomach. What is commonly known as a biuret reaction persists only as long as any protein properties remain, and as near as can be detected no such reaction is present after tryptic digestion takes place, showing that the process has gone to the stage of producing simple bodies as amino acids and hexone bases.

The term hexone bases is given to a group of derivatives from the protein molecule, the most important ones being arginine, lysine and histidine. They are all soluble, crystalline substances widely distributed in nearly all proteins.

The term amino acids is given to a class of substances that are found making up a great portion of the proteins. Among some of the most common are glycine, obtained from gelatin and very soluble in water; leucine, found to the extent of 30 per cent in some of the proteins and, being so abundant, is considered to be very important; tyrosine, found in all common proteins except gelatin, is slightly soluble in water and crystallizes in bundles of fine needles; tryptophane, occurs in most proteins and to it are ascribed the many peculiar color reactions.

Trypsin is one of the most active of enzymes in the human body, but about its real nature very little is known, as it cannot be separated from substances in combination even to approximate purity. It is very soluble in water and easily digested by pepsin in the presence of hydrochloric acid. Its optimum temperature is about 40° C. and its action best in a weak alkaline medium.

Amylopsin may rightly be called the second most important enzyme of pancreatic juice and its principal action the digestion of

starch. It differs from salivary amylase in that its action is more rapid and powerful and is also capable of breaking down unboiled starch. It transforms the starch into malt sugar through several intervening stages of dextrins. Found in combination with this enzyme there exists a small amount of maltase which is capable of transforming the malt sugar into glucose. This inversion was for a long time ascribed to the intestinal ferments, but has since been satisfactorily proven. By means of the combination of the above two enzymes the carbohydrates are made ready for the process of absorption.

Pancreatic steapsin possesses a double action. It is capable of forming an emulsion with fats. In both of these actions steapsin is assisted by alkaline bile so producing soaps.

INTESTINAL DIGESTION

Up until recent investigations have been made it was thought that there were present in the intestines only two enzymes. One was called invertase and the action ascribed to it was that of transforming cane sugar into dextrose and levulose. The other was given the name lactase, whose action consists in the inversion of the sugar of milk or lactose. At a later period a third, given the name maltase, whose action is to invert dextrose that has escaped salivary and pancreatic digestion, was isolated.

Erepsin, but recently described, possesses the power of breaking down albumoses and peptones. It will not digest true proteins.

Though the work of breaking up the peptones and albumoses has been ascribed to the juices of the pancreas, more properly trypsin, this does not go to prove that no such enzyme as erepsin exists. The power of erepsin as compared with trypsin in breaking down these substances is much greater and should be considered very important.

Enterokinase as existing in the intestines is not to be considered as an enzyme, but only as a body capable of activating

the trypsinogen producing trypsin, which, were it not for this change, would not be able to digest the protein substances.

Bile is a liquid secreted by the liver cells which varies in color and consistency according to the length of time that it remains in the gall-bladder. Freshly secreted bile is of reddish-brown or golden-yellow color with a specific gravity of 1.008 to 1.010. Upon remaining in the gall-bladder for any length of time it becomes partially oxidized and assumes a darker color. Water is absorbed from it through the wall of the bladder and mucin from cells in the wall of the bladder and surrounding glands is added to it, thus increasing its specific gravity to 1.030 or 1.040, and its consistency becomes more viscid. Bile as generally observed is defined as a viscid, dark brown fluid secreted by the liver cells.

Bile is alkaline in reaction and consists of water, mucin, inorganic salts, fat and cholesterin; also two well defined pigments, bilirubin and beliverdin.

A portion of bile may be an excretion, but the greater share of it assists in the digestive processes. It transforms the acid chyme into alkaline chyle, a proper medium for pancreatic and intestinal ferments to work in. It assists in the processes of emulsion and saponification.

CHAPTER XLIV

INNATE CONTROL OF DIGESTION

We have taken up in detail the structure of the alimentary tract and the accessory glands which form a secretion which is thrown into it, and which aid in the general digestive process. We have studied the mechanical activity of the organs of digestion and the chemical combinations which are made and which have various actions upon the foods which are passing through the canal. To assume, however, that this concludes the subject of digestion would be entirely erroneous. We have yet to consider that phase of digestion which, for want of a better term, we will call the mental digestion. This has to do with the controlling factor of all the mechanical and chemical changes which occur throughout the entire alimentary canal.

It would be as illogical to assume that digestion could occur without the impelling action of the Innate Intelligence through the nervous system as to assume that an individual could live without the brain, through which Innate manifests herself by every sign of life in the human mechanism. We know, for example, that to produce water we must bring into relation with one another the two substances of hydrogen and oxygen in the proportions of two to one. The work performed in bringing the two substances together is mechanical, while the union of the two substances is a chemical process due to a chemical affinity which they bear to one another. However, to assume that water is formed in this manner without the mental process having first occurred in the mind of the operator is highly illogical.

The thought, the mentality of the operator, is the first and controlling factor in the process. As a result of this mental process the necessary mechanical work is performed, and the knowledge of the laws of chemistry assure the operator of the success of the experiment.

The mental process in the human body is relatively as important in the accomplishment of digestion. Here it is true that the laws of chemistry obtain, as they always have and always will, but the activity of the Innate Intelligence in sending mental impulses through the nervous system acts as a controlling force in deciding the mechanical activity, and the so-called selective influence of the secreting cells for certain kinds of chemical substances.

Having then firmly established the importance of the nervous system in offering itself as a medium through which Innate Intelligence controls the mechanical and chemical processes of digestion, let us turn our attention to a more detailed study of this activity.

We cannot assume that the nerves which pass to and supply the alimentary canal all emit from one or two intervetrebral foramen. The salivary glands which pour the secretion into the buccal cavity are supplied with spinal nerve and cranial nerve fibers. These spinal nerves emit from the cervical intervetebral foramen. Passing down the spine it is clinically true that the pharynx and the oesophagus receive fibers from the foramen at right of S. P. The stomach receives fibers from the nerve trunks emitting from the left foramen of the S. P. region, and in all probability all the foramen from this point to the lower extremity of the spine give off fibers which pass to some part of the intestinal tract.

Physiologists generally concede "that the action of the salivary glands is under the direct control of the nervous system." There is no question but that it is under the control of Innate Intelligence through the nervous system. The presence of food

in the mouth calls for the presence of saliva to act not only in a chemical capacity but to aid in breaking up the foods by moistening and softening them. As soon as the food reaches the mouth afferent impressions are started along the course of the afferent nerves to the brain, where an interpretation is made and Innate becomes aware that saliva is required. As a result of this interpretation impulses are sent to the secretory cells of the salivary glands and other serous and mucous glands in the mouth, and saliva is the result of the response of these cells to Innate direction. Sometimes the saliva flows freely even when food is not taken into the mouth. The sight or the smell of food is sometimes sufficient to induce the secretion. In this event the afferent impressions are carried not along the afferent nerves supplying the mucous membrane of the mouth, but along the fibers of the optic or olfactory nerves. However, the interpretation is made and the efferent impulses are produced, so that the ultimate result is the same.

The process of swallowing now begins and here, too, we must depend upon the controlling influence of the Innate Intelligence to produce the mechanical action. Part of this action is under the control of Innate Intelligence and part of it under the control of educated intelligence. It is entirely a muscular effort, and the cycle must be made here just the same as in the secretion of saliva. At every point along the course, where the bolus of the food comes in contact with the mucous membrane of the wall of the alimentary canal, an afferent vibration is set up, resulting in an interpretation in the mind. The interpretation by Innate Intelligence results in the production of efferent impulses which are carried along the efferent nerves to points immediately behind and immediately in front of the food bolus, producing relaxation ahead and contraction behind, thus causing the food to pass from a point of high pressure to one of low pressure at all times.

Often gaining entrance into the stomach there are both

chemical and physical activities. The stomach walls constantly undergo a change of position and shape churning and mixing food that it may be brought into closer relationship with the gastric juices. The chemical activity of the glands of the stomach in forming gastric juice is the direct result of an Innate action in sending mental impulses along the efferent nerves to these glands, and this action of Innate Intelligence is in turn the result of afferent impressions started from the mucous membrane of the stomach. The same is true of the mechanical activity of the stomach.

After undergoing gastric digestion the food passes through the pyloric valve which acts in response to the so-called acid control. The basis of acid control is good if carried far enough, but to say that the acidity of the food in the stomach causes the valve to open and to leave out of the consideration the cycle through the nervous tissue is leaving the story half told. As soon as a mass of food in the stomach becomes acid in reaction, impressions are carried along the afferent nerves from the mucous membrane of the stomach, and upon interpretation Innate Intelligence is aware that this food has gone as fas as is possible in the process of digestion in the stomach and immediately impulses are sent over efferent nerves to the muscular fibers of the pyloric valve causing them to relax and allowing the food to pass.

In the secretion of the bile in the liver, the pancreatic juice in the pancreas, the various digestive substance in the intestinal wall, we must always apply this complete cycle to the process because without it there could be no harmony of action nor certainty of results. Not only must this cycle be applied to the glandular activity, but also to the mechanical activity and to the action of those cells which exercise the so-called selective influence in the absorbing mucous membrane.

We must not be too prone to assume the narrow viewpoint in explaining the activity of a certain part of the body. To

view only that particular part to the exclusion of the rest, is to lose sight of the vital kernel, which is so all important. The consideration of every system of the body should be in conjunction with every other system in order that we may have a broad viewpoint. The consideration of every organ in a system must be in conjunction with every other organ in that system.

In conclusion then let us make a summary of the Innate control of the entire digestive system. We must always remember that there is present in every human body an Innate Intelligence which controls and is aware of, not one action but every action in that body. In the process of digestion this Innate is in control, not of one gland, but of every gland and cell which has to do with the process of digestion. Before any normal, physical or chemical change can occur in the digestive tract there must first be the mental impulse which is productive of that change, and before this mental impulse is produced and dispatched there is the interpretation of an afferent impression by which Innate Intelligence is made aware of the necessity for such activity.

SECTION IX

EXCRETION

CHAPTER XLV

URINARY APPARATUS

Normally we have taken into the body various substances which are of use in maintaining the cells as units, in a normal functioning condition. We should, however, remember that all material taken in is not used, because those elements which are essential are held in compounds with other substances, which are not necessary. It is in the great workshop of the body that the essentials and the non-essentials are separated, and those which are unnecessary are then sent on their journey to be eliminated in various ways. We have four principal methods of eliminating waste products from the body: By means of the skin, the kidneys, the lungs and the intestinal tract. The last two are taken up under the respective subjects of the respiratory system and the digestive system. The skin and the urinary apparatus, however, are to be considered under individual classifications.

The Structure of the Kidneys

The kidneys form the principal part of the urinary organs, although properly we must include the ureters, the urinary bladder and the urethra.

Located in the abdominal cavity, behind the peritoneum, the kidneys are two in number, one on each side of the spine. The upper extremity is opposite the twelfth dorsal vertebra, while its lower extremity is opposite the third lumbar vertebra. In

shape the kidney resembles that of a bean, with a convex and a concave portion. The concave surface looks toward the inferior and toward the axis of the body. In length, the kidney is about 4½ inches, in breadth, about 2½ inches, and in thickness, about 1½ inches; weighing from four to six ounces, although somewhat larger and consequently heavier in the male than in the female. The right kidney is usually placed slightly lower than the left owing to the thickness of the right lobe of the liver as compared with the thin lobe on the left side.

The kidney is surrounded by a fibrous capsule known as the tunica fibrosa, but just outside this fibrous covering is a mass of fat (capsula adiposa) forming an ensheathing capsule around the tunica fibrosa. This adipose covering is in turn held in place by a thin areolar layer of connective tissue known as the facia renalis. If the tunica fibrosa is striped off the surface of the kidney it is seen to adhere closely to the structure of that organ, and when removed shows small process like projections which have extended into the kidney substance. Beneath this fibrous capsule, between it and the kidney, is a very thin layer of non-striated muscular tissue, through which these projections of the fibrous capsule pass on their way to the kidney substance. Of a deep red tint, the kidney is of very dense, close structure.

If a longitudinal section is made of the kidney, separating it into an anterior and posterior division, it will be found that there is a central cavity with an outlet on its inner border. This outlet is known as the hilum and is found at the concave inner border of the kidney. The central cavity which communicates with the external by means of the hilum is known as the renal sinus and is lined throughout its extent by a prolongation inward from the tunica fibrosa. Contained in this sinus are the blood vessels and excretory duct which enter and leave by means of the hilus.

Near the lower border of the kidney, the ureter, which drains the urine from it into the bladder, is constricted to the

normal size which it maintains from here downward to its termination in the bladder. Above this point, however, it is dilated in the shape of a funnel, with the apex downward and the wide expansion in the sinus of the kidney, filling all of this space except that occupied by the blood vessels. This dilated extremity at the superior end of the ureter is known as the pelvis of the ureter, and after its entrance is affected at the hilus it is contained in the sinus.

To suppose that the inner surface of the sinus is smooth is erroneous. It should be remembered that the pelvis is fitted snugly in it, just as a lining membrane, and that the convolutions of the one must follow the convolutions of the other. The pelvis, instead of being smooth walled, is divided into two main divisions (sometimes three) which are known as major calices. The calices may be said to resemble two large cups, which empty into the main cavity of the pelvis. At the bottom of the cups we have further subdivisions (cuplets) which are known as the minor calices, and which empty into the major calices. These minor calices are about ten or twelve in number, and each one has projecting into it the apex of one or more pyramids, which lie in the substance of the kidney, with their apices toward the sinus and their bases toward the outer surface of the organ.

The substance of the kidney has a supporting framework of connective tissue with, however, no definite arrangement of its walls. The parenchyma of the organ is composed of uriniferous tubules, so called because it is in them and their dilated extremities that the urine of the kidney is formed. They are very minute tubules, which are in parts of their course convoluted and irregular, while in certain parts they are straight and arranged in definite order. This leads to the division of the kidney into a cortical and a medullary portion. The cortical portion is the outer part, about one-third of an inch in thickness, and the tubules here are irregular in their course. The medullary portion is the part next the sinus, about two-thirds of an

inch in thickness, and it is here that the tubules are straight, and parallel with one another.

The medullary portion of the kidney is composed largely of uriniferous tubules arranged in straight lines, and forming by their arrangement from twelve to twenty pyramids, known as medullary pyramids. These medullary pyramids lie with their bases toward the outer border of the kidney and their apices toward the sinus, projecting into the minor calices. (One, two or three apices may be projected into one minor calix.) The tubules converge at the apex of each pyramid, where they have been gathered from their entrance at various parts of the base. Many of the minute tubules which are present as individual tubules at their points of entrance into the medullary pyramid, join one with another until at the termination at the apex, there are only about 16 to 20 tubes, which empty by as many openings into the minor calix, in which their particular pyramid terminates. This forms upon the projecting apex an area which is perforated with minute openings, and the entire appearance which it presents gives it the name of area cribrosa. The projecting end of the medullary pyramid is known as the renal papilla.

The pyramids are separated from one another by the intervention of connective tissue which contains blood vessels, nerves, lymphatics, and which is in reality a continuation of the cortical substance, toward the sinus of the organ. These masses of connective tissue form columns between the pyramids and these columns are known as the columns of Bertin, or the renal columns. The columns of Bertin are really masses of cortical substance projecting toward the sinus.

The cortical substance of the kidney lies just outside the medullary substance, and here the uriniferous tubules are not arranged in any definite course, but form convolutions and irregularities, until the appearance under the microscope is of a mass of tubes closely packed, but with no definite arrangement. The cortical substance is granular, of a dark red color, and upon

microscopic examination displays the existence of small ray-like projections of straight tubules from the bases of the pyramids toward the outer surface of the kidney. These are known as the medullary rays and are placed with their bases against the bases of the medullary pyramids and gradually tapering toward their apices near the tunica fibrosa, although they do not in reality reach the surrounding capsule. That portion of the cortical substance which is found between the rays, is known as the labyrinth, and it is here that we have the irregularity of the tubules.

The uriniferous tubule has its beginning in the cortical substance by means of a small, blind, dilated extremity known as the capsule of Bowman, or the Malpighian capsule. Within this capsule is found a minute mass of microscopic capillaries, forming what is known as the glomerulus. The glomerulus and the capsule of Bowman form what is known as the Malpighian body, which varies in size from 120 to 200 micromillimeters. Entering the capsule of Bowman opposite the point of exit of the uriniferous tubule, we have a minute arteriole which carries the arterial blood to the capillary mass, and finding its exit from the capsule of Bowman is a minute venule. These blood vessels are known as the afferent and efferent vessels, dependent upon whether they supply or drain the glomerulus.

The capsule of Bowman is composed of a retiform connective tissue lined with flattened or cubical (in the infant sometimes columnar cells are found) epithelial cells, forming a distinct lining membrane. At the point of entrance of the afferent vessel this lining is reflected upon the glomerulus, and offers itself as a covering for it. There is then a space left between the epithelial lining of the capsule of Bowman and the epithelial covering of the glomerulus, that contains fluid which will later become urine, and the amount present depends upon the activity of the Malpighian corpuscle.

From the capsule of Bowman to the termination of the uriniferous tubule in the minor calix, it pursues a very changeable

course, and this gives rise to the division of the tubule into several sections. At the point where it leaves the capsule it is constricted and is known as the first convoluted tubule. Leaving the convoluted form it becomes spiral in its course, and this is known as the spiral tubule. Now the tubule enters the Malpighian pyramid, where for a short distance it approaches in a straight line toward the sinus, and this section is known as the descending limb of Henle. After a short progress toward the sinus the tubule then is bent upon itself, making a hairpin curve, which is known as the loop of Henle. The tubule now ascends toward the cortical substance and in its course here is known as the ascending limb of Henle. After ascending for a short distance the tubule again enters the cortical portion, where at first it is slightly convoluted, and is known as the second convolution. This second convoluted tubule terminates in a junctional tubule which enters the medullary substance at right angles to the main tubules in it, and here empties into a straight collecting tubule. These straight collecting tubules unite with one another to finally form 16 to 20 main ducts, the openings of which form the area cribrosa, and these large ducts are known as the ducts of Bellini.

Throughout the entire uriniferous tubule we have a continuation of the ephithelial lining which is present in the capsule of Bowman. Sometimes of the squamous type, sometimes of the cubical type and sometimes of the columnar type, it varies in different parts of the tubule, as does also the diameter of this minute duct.

Blood Supply of the Kidney

The renal arteries supply the kidney, one of them being given off to each organ from the aorta, and entering the kidney at the hilus between the renal vein (anterior) and the ureter (posterior). After gaining admission to the sinus, the renal artery divides into four or five branches which pass to and supply different parts of the organ. It should be remembered that because of the proximity of the pelvis of the ureter and the

sinus of the kidney that the renal artery is ensheathed between the two of them. Following the surface of the sinus the large branches of the renal artery give off interlobular arteries which enter the substance of the kidney through the columns of Bertin. Upon reaching the boundary between the cortical and medullary substance at the bases of the medullary pyramids, the arteries form incomplete arches, which form a plexus known as the arcuate plexus. From the arcuate plexus are given off branches for the supply of the cortical and of the medullary substances.

The vessels which enter the cortical substance are known as intralobular arteries and they, in turn, break up into finer and finer branches, ultimately forming the afferent arterioles which enter the capsule of Bowman and the capillaries of which form the glomerulus. Draining the glomerulus we have the efferent venule, which, after its exit from the capsule of Bowman, again breaks up into a capillary network which distributes itself around the tubules. This capillary network is in turn drained by venules which unite and reunite finally to form the intralobular veins which empty into the veins of the arcuate plexus.

Entering the medullary substance we have the arteries which follow the same course as do the tubules in this part. These are known as the arteriolae rectae, and after entering the substance of the medullary portion they break up into capillaries which in turn drain into the venae rectae. The venae rectae leave the medullary substance in the same manner that the arterioles enter, namely, in straight vessels, which empty into the arcuate plexus of veins, and this blood is then carried to the sinus and thence to the external by means of the interlobular veins which by uniting form the renal vein.

Ureters

The ureters are two in number extending from each kidney and conveying the urine from here to the bladder, which acts as a reservoir. At the superior extremity the ureter ends in the dilated funnel-shaped tube which fits into the sinus and follows

the wall of this cavity. Beginning in small cup-shaped pouches (minor calices), these converge and form the major calices, which in turn unite and form the pelvis proper. The ureter now proceeds to the inferior and enters the bladder at its base, one on each side of the median line. It is about ten inches in length, and 1/6 inch in diameter, and is composed of three coats, the fibrous, muscular and mucous.

The fibrous coat is the external, and is continuous with the fibrous covering of the kidney (tunica fibrosa) at the superior, and the outer fibrous coat of the bladder at the inferior.

The muscular coat is found just beneath the fibrous, and consists of two divisions in part and three in part. At the superior in the dilated portion of the tube we find just two layers, the outer circular, and the inner longitudinal. The circular layer is thickened somewhat in the minor calices and forms minute sphincters around the individual papillae which project into the cups. The longitudinal layer is lost in the minor calices. In the main tube below the pelvis, we note another layer of muscular fibres, an additional longitudinal layer outside the circular.

The mucous membrane of the ureters is of the transitional type placed upon a basement membrane, and containing some few racemose glands.

Bladder

The bladder acts as a reservoir for the urine containing it in the quantity of about a pint without undue discomfort. It is placed in the pelvic cavity between the pubes and the rectum in the male and between the pubes and the neck of the uterus and the vagina in the female. Its size varies, markedly dependent upon the degree of distension. If distended greatly the bladder may be forced to lie partly in the abdominal cavity, and sometimes almost as high as the umbilicus. When distended to an ordinary degree the bladder measures about five inches longitudinally, 4½ inches laterally and three inches antero-posteriorly. Upon examination of the inner surface it is found to vary, de-

pendent upon the amount of urine contained. If distended the mucous membrane and wall show a smooth surface, and if collapsed, longitudinal folds make their appearance. The bladder is composed of three coats corresponding to those of the ureters. The outer is fibrous, the middle muscular and the inner mucous.

The outer fibrous coat is continuous with the fibrous coat of the ureter, and merely consists of white fibrous tissue.

The muscular coat is divided into three layers; the outer one is longitudinal, the middle circular and the inner longitudinal. These muscular layers are all formed of nonstriated muscle fibers.

The mucous membrane is of the transitional type as is that found in the ureter, and the cells are placed upon a basement membrane which in turn rests upon the areolar propria. There are no glands in the mucous membrane of the bladder.

Urethra

The urethra is the tube which serves to convey the urine from the bladder to the external and differs in the male and female. In the former it is about seven or eight inches in length and in the latter about one and one-half inches. The ureters vary somewhat in structure in the male and female, but this distinction is of no physiological importance.

CHAPTER XLVI

FORMATION OF URINE

In the formation of urine the student finds himself face to face with the question of whether the urine is formed by the selective influence of the cells lining the uriniferous tubules and glomeruli under the control of Innate Intelligence; whether to the ability of these cells so governed to secrete the constituents of the urine from the materials they take from the blood, or whether the entire process of urinary secretion may be founded upon the purely mechanical principles of osmosis, filtration and diffusion.

Bowman first established the famous "vital theory" in connection with the secreting of urine, founding his idea upon the fact that the epithelial cells here were very similar to the secreting epithelial cells in other glands. He assumed that the Malpighian bodies had the function of extracting the water from the blood of the glomerulus and starting it on its course through the uriniferous tubule. It was further his idea that in the uriniferous tubule itself, the epithelial cells had the peculiar power of secreting from the blood which bathed them, all the other constituents of urine; the urates, phosphates, etc.

Ludwig differed entirely from Bowman in that he tried to explain every phase of urinary secretion by the laws of chemistry and physics. This has come to be known as the physico-chemical theory and each one of the two have had many supporters. Ludwig, upon examination, found that the afferent vessels entering the capsule of Bowman was much larger than the efferent vessel leaving, and at once realized that this was not as is found in other capillary areas. Arterioles in general by their peripheral resistance serve to dam back the blood in the arteries and lessen

the pressure in the capillaries. Here, however, there is practically no peripheral resistance, and as a consequence the capillary pressure is much greater than the ordinary. This fact, coupled with the fact that less blood was flowing out from the capsule of Bowman than was entering, led Ludwig to the belief that the loss of some constituents in the blood was the result of physical laws.

Ludwig's theory maintained that the passage of the dilute urine of the Malpighian body into the capsule from the glomerulus was merely a filtration process, the result of potential energy expressed by the lateral pressure in the glomeruli, which in turn was due to the action of the heart in maintaining the vascular pressure. Knowing that the urine in the capsule of Bowman was more dilute than that in the pelvis of the ureter, some explanation had, therefore, to be offered as to where and how this change occurs. There seemed to be no question but that it occurred in the uriniferous tubules, and then the only question was as to how this change occurred. Was it due to selective influence of the cells, to osmosis, or diffusion? Ludwig answered it by offering the explanation of diffusion, maintaining that the cells of the tubules were admirably fitted for this process, and that the very dilute urine (compared with the blood) had much of its water reabsorbed by these cells and again taken up by the blood.

REABSORPTION IN THE URINIFEROUS TUBULES

There has been some debate as to whether there is a reabsorption occurring in the tubules of the kidney, and in order to establish this fact or to disprove it some interesting experiments have been performed. If the ureter pressure is raised by a ligature near the bladder and some easily detected foreign substance is introduced into the ureter, it is found that it soon appears in the blood. This, however, cannot be considered as a proof that reabsorption occurs in the kidney normally, because when these conditions are introduced the pressure in the pelvis

and thus the tubules is markedly increased above the normal. Some investigators have succeeded in removing large parts of the uriniferous tubules in the attempt to decide the question of reabsorption. It was first claimed that when the entire medullary portion was removed the amount of urine was markedly increased, perhaps to several times the normal. Later investigations showed, however, that the entire medulla could not be removed, but that if a large part of it was eliminated the increase of urinary elimination was marked. The conclusions drawn from these findings were that when the tubule was removed reabsorption could not occur, and as a result the urine was increased in quantity. Another explanation, however, can be offered which is more consistent with the knowledge of the presence of an intelligence in the body which has the power of controlling and meeting the various conditions which arise. While it is true that the glomerulus gives off water and salts, and the uriniferous tubules give off the majority of the other constituents of the urine, still if the one is damaged to such a degree that it cannot carry out its function it is only reasonable to suppose that the other will do an excessive amount of work in the endeavor to adapt itself to the new conditions.

When, therefore, the medullary part of the kidney is largely removed, and the uriniferous tubules are thus greatly shortened, the Innate Intelligence in the brain becomes aware of this changed condition and realizing that the tubules are not to be counted upon, she tries to adapt herself to the changed conditions by sending down more impulses to the Malpighian bodies, thus causing them to function in excess. Now it is not the function of the Malpighian bodies to secrete urates, phosphates, etc., and the excess of secretory impulses is utilized in the formation of more water and salts. This, then, accounts for the increase in the amount of urine, and its degree of dilution when part of the medullary substance is removed. Another experiment which has been successfully performed is that of ligaturing the renal portal veins which

are the efferent veins coming from the glomerulus. When this is done it does not stop the blood supply to the glomerulus, but does cut it off from the second capillary network in the kidney. The urine is thus decreased. It is argued that if the function of the Malpighian capsule is to form a very dilute liquid, part of which is absorbed in the tubule, that there would be no interference with the first function, but that the latter would be interfered with or entirely stopped because of the absence of blood in the tubule, and that the urine would be greatly increased in quantity. This experiment does not prove nor disprove anything, because while the blood supply to the glomerulus is not cut off it is in a condition of stasis, and the work performed by the glomerulus cannot be said to be normal. In reviewing the situation from the standpoint of these experiments which have been made either in support of the theory holding that reabsorption takes place in the tubule or for the purpose of disproving it, we may come to the conclusion that there is no good evidence that reabsorption does take place, and as that is one of the essential features of the physico-chemical theory, the theory may be said to be weakened in some degree. To maintain that pressure of serum in the kidney has nothing to do with the amount of urine secreted would be contrary to all indications. The amount of urine secreted depends somewhat upon the serous pressure and varies with it, but this does not of necessity prove that there are no secretory nerves in the kidney, and that the secretion depends upon the variation in pressure. It may safely be said that the action of the kidney is primarily controlled by the action of Innate Intelligence through the nervous system. This action is modified in some degree by the conditions of pressure in the kidney, which in turn are directly under the control of Innate.

To say that Innate Intelligence, by means of the cells of the glomerulus and those of the tubules, is able to exert a selective influence upon certain substances in the blood and pass them through their bodies to form a part of the urine, and to

deny the fact that there are secretory nerves passing to the kidney is a direct contradiction. The ability of a cell to select from the fluids which bathe it, the materials which when passed through it are a part of a certain solution, is, in itself, the secretory ability, and must of necessity be controlled by Innate Intelligence through the secretory nerves. Some physiologists maintain that the kidney has no secretory nerves because the amount of secretion varies with the serous pressure, but this in itself is not proof.

EXTIRPATION OF THE KIDNEYS

Extirpation of one kidney is often made, and in this event its fellow, under the adaptative influence of Innate, enlarges and does the work of its mate. Extirpation of both kidneys, however, always proves fatal because of the autointoxication thus produced. The uric acid, urates and other constituents of the urine cannot be eliminated and as a result are dammed back and retained in the blood. Death results in a very few hours after such an operation.

FLOW OF URINE FROM THE KIDNEYS TO THE BLADDER

This occurs through the ureters which, in turn, gain their urine from the uriniferous tubules. As the molecules of urine are secreted by Innate through its control over the glomeruli and tubules, the urine which is contained in the tubules is forced onward and out into the pelvis of the ureters by way of the minor and major calices. There is no special rate at which the urine enters the bladder. Innate controls this, dependent upon her interpretation of the necessity, which may be altered by violent exercise, the presence of food in the alimentary canal and possibly to some degree upon the breathing. Shortly after a meal (15 or 20 minutes) the rate of secretion and thus expulsion into the bladder is increased, and as in the case of

exercise and deep breathing is probably due to the increased serous pressure.

Upon an average we may say that several drops of urine enter the bladder at the same time from one of the ureters, and these periods of entrance are several minutes apart. The ureters, however, do not empty their secretions at the same time. This passage of the urine from the kidney to the bladder depends upon the peristaltic action in the ureter, which is produced by Innate when the necessity arises. At the point of entrance of the ureter into the bladder it pierces the external and muscular coats diagonally, and then lies for about half an inch between the muscular and mucous coats, before turning toward the cavity and emptying therein. There is also a small papillary flap over the opening which, together with the diagonal course assumed by the ureter, serves to prevent the urine from regurgitation. It is probable that the pressure of the urine in the ureter is about the same as that of the blood in the glomerulus.

Micturition

This is the act of voiding urine from the bladder to the external through the urethra. It is in part an educated and in part an Innate action. There is a contraction of the muscles of the bladder itself, which are of the nonstriated variety, and this action is Innate. Also the relaxation of the sphincter muscles by inhibition is Innate. On the other hand, the contraction of the abdominal muscles is an educated action.

The desire to urinate arises from the distension of the bladder and consequent pressing of it upon the surrounding pelvic and abdominal viscera. Micturition is first begun by the contraction of the abdominal muscles, thus raising the pressure in the bladder and producing added vibrations for the afferent nerves passing to the motor and inhibitory centers through which the bladder walls and the sphincter muscles of the urethra are controlled by Innate. Because of these afferent impulses an interpretation occurs and efferent impulses are sent

down to the bladder and urethra, motor to the former and inhibitory to the latter, thus producing the act of micturition.

Inability to produce micturition may be accounted for in several ways. It may be that it is due to an obstruction (calculus) in the urethra, or it may be due to a lack of motor impulses being supplied by Innate to the muscular fibers of the bladder or the abdominal wall. If the latter is the case it is due to a sublaxation of the spine in the region of the lumbar vertebrae.

INNATE CONTROL OF THE URINARY APPARATUS

We have for the sake of comparison set forth the two foremost theories of urinary secretion, which have been advanced up to the advent of the Chiropractic idea. Ludwig attempted to explain the secretion of urine by his physico-chemical theory, which was based entirely upon the laws of physics and chemistry. Bowman advanced a long step and brought forward his famous vital theory. This idea of Bowman was very near the truth, and if he had advanced still another step he would have been grounded on the firm basis of intelligence which Chiropractic rests upon today.

Here in the secreting cells of the glomerulus and those lining the uriniferous tubule we have the expression of a vital energy just the same as is expressed in every other part of the body, but to say that the vitality is latent in the cell itself would give to each individual cell an intelligence which would have no intimate connection with any other cell whose function it would be to perform the same work. Thus there would be no unity of action between the secreting cells of the kidney, nor could the activity of this organ as a unit be concerned with any other condition in the body, of which it is but an integral part. In reality impressions pass along the afferent nerves to the brain acquainting Innate with the composition of the substances which are contained in the serum, and as a result of this interpretation efferent impulses are sent along the course of the secretory nerves supplying the kidneys, and the cells because of the vitality imparted

to them by these impulses are able to offer themselves as agents by means of which Innate takes from the serum, the urates, phosphates, etc., which are necessary in the formation of urine.

After this has been accomplished Innate is again made aware of the presence in the uriniferous tubules of the substances so formed, and upon an interpretation of the latter afferent impressions, motor impulses are sent to the tubules which produce a peristaltic activity, forcing the urine out to the minor calices, the major calices, and finally to the main cavity of the pelvis of the ureter. Here it remains until by afferent sensory impressions Innate is informed of the presence of several drops of urine which she causes to be expelled into the bladder by sending out motor impulses and causing a contraction of the muscle fibers of the ureter.

In the bladder we have the urine gathering in larger and larger quantities until the bladder is full. By the afferent impressions Innate is made aware of this condition and sends out motor and inhibitory impulses, the former to the muscular fibers of the bladder and those of the abdominal muscles while the latter are sent to the sphincter muscles of the urethra and bladder.

CHEMISTRY OF URINE

The three principal food stuffs are proteins, fats and carbohydrates which in undergoing digestion give off waste products consisting largely of nitrogen, water and carbon dioxide. The protein metabolism is not carried to the end of nitrogen formation, but ends with the formation of urea.

Regarding the breaking down of protein bodies, two old theories exist. The one holds that the nutritive elements of the protein complex are absorbed and become a part of the living cell, which changes their chemistry resulting in the formation of waste products. The other states that there is in the body a circulating protein which does not become part of the structure of the cell but is changed by forces inherent in it.

It is undoubtedly a fact that the proteins are broken down

into amino acids and absorbed. The nitrogenous portion of them is largely broken up into ammonia, which later is converted into urea. A certain percentage of the residue especially that rich in hydrogen and carbon undergo oxidation. In so far as reconstruction of the protein in the body is concerned it is claimed that only enough of it is built up to replace worn-out tissue though this idea is purely a theoretical one.

The kidneys are considered to be those organs which have for their function the separation of the constituents of urine from the serum and voiding them to the external. Not only are they concerned in this elimination but also in part possess a definite secretory function. This secretory function is a selective one and is the power of the small cells of epithelium which form the kidney tubules to separate from the serum the foods that are still valuable from those that are worthless.

The blood is a circulating fluid which is said to possess a definite osmotic pressure due to certain of its constituents. If these constituents are higher than normal the kidney becomes very active in allowing the excess to pass out.

The volume of urine excreted daily varies much in amount due to different conditions. The normal amount in 24 hours is 1500 c. c. or approximately three pints, which amount is increased normally by vegetable diet, ingestion of liquids, nervous excitement and renal arterial tension. It is decreased normally by perspiration and all conditions opposite to those which tend its increase. In cases of diabetes mellitus and diabetes insipidus, hypertrophy of the heart and amyloid degeneration, all of which are abnormal conditions, the urine is increased in quantity. There are some diseases of the blood and liver, also febrile diseases, in the course of which the quantity of urine is less than normal. This is also true in acute nephritis, renal congestion and the onset of dropsy.

Normal urine is of amber color, but this color is not at all constant, varying with the concentration and water consumption. Certain substances such as rhubarb and senna possess a marked

tendency to produce in urine a yellowish discoloration. This is also true when the quantity is decreased and the pigments are present in greater or less degree. The normal coloring agents in urine are two in number, known as urobilin and urochrome. Urobilin is derived from a bile pigment which it closely resembles, while the exact source of urochrome is not definitely known.

Certain pathological conditions possess marked tendency to alter the normal color of urine. In cases of haematuria, jaundice and in all febrile diseases the color is deeper. In haematuria it is red; in jaundice, where there is the presence of bile in the urine, the color is green, while in some other cases where tumors exist in the body a black discoloration is noted, due to the agent melanin. In conditions such as diabetes, polyuria and anaemia the urine is very pale, thus we can see that the color of urine varies in different conditions, for which some of the main causes are the quantity of urine, the degree of concentration and the amount of pigment present. Indican imparts a bluish color to the specimen, and if present in sufficient quantities forms a blue precipitate. The pale color is usually due to the lack of coloring agents, the increased consumption of watery constituents and the decrease in the amount of solids. In febrile diseases the substance which imparts color is known as uroerythrin. The presence of the above coloring agents may be detected by Heller's ring test, the nitric nitrous acid test, but is best shown by means of the spectroscope.

Urine possesses a characteristic aromatic odor which changes rapidly upon the specimen standing because of the bacterial action and the development of the odor of ammonia resulting from the decomposition of urea. When organic matters of urine break down, the putrefactive changes bring about certain disagreeable odors. Some vegetable foods such as asparagus or onions impart their characteristic definite odor to this excretion. Turpentine, as well as certain medical remedies, also give to it an odor which is especially marked. Under pathological conditions certain ingredients are present such as sugar in diabetes which imparts a

sweetish odor; in cancer the putrid or fetid odor is characteristic, and in cases of fistula emptying from the intestinal tract into the bladder the fecal odor is manifest.

The normal reaction of urine in the first twenty-four hours is acid, due largely to the presence of acid salts rather than the free acid. Of these acid salts di-acid sodium phosphate is the most important. In certain forms of diet there may be found an alkaline reaction which is due to the elimination of carbonates from organic solids. This alkaline reaction should not be confused with the same reaction observed when urine has stood for any length of time, as in this case we find ammonia present, due to the decomposition of urea. Litmus paper is the best indicator for all practical examinations, as the measurements by any other means, of alkalinity or acidity, are very uncertain.

Some of the most important substances found in urine are alkaline salts, compounds of calcium, nitrogen, urea, uric acid and ammonia. In considering the excretion of alkaline salts under consumption of mixed diet, it is quite impossible to reach any definite conclusion, as there is a great variation in the amount of different substances present. On a cereal diet the urine shows a high potash and phosphoric acid content, while on eating potatoes there is present a small amount of sodium and a great deal of chlorine. Potassium salts as well as chlorine are also present in cases where there has been an ingestion of meat or vegetables. The source of calcium is water, though small amounts of this are found in the vegetable foods that the human individual consumes. There is but a small fraction of this substance found in urine, and under ordinary conditions it is almost impossible to detect its presence, especially when the temperature is high or when its stability is overcome by the presence of uric acid,

The excretion of nitrogen is very important and gives in many cases an idea of the problems dealt with in considering the general metabolism of the body. Most of it passes out of the system in form of urea, though other substances containing it, such as uric acid, ammonia, creatinin, etc., should not be lost

sight of. Many methods are in use to determine the quantity of nitrogen excreted, and although these methods determine this amount present in certain substances quite accurately, in others the results obtained barely reach the approximate degree.

Urea is another one of the important constituents of urine. About 33 to 35 grammes are excreted daily, which amount would be about 2 per cent of the total urine. This amount varies greatly with the kind of diet; that rich in proteins results in the excretion of large amounts of urea, more especially abundant about three hours following the meal. It is claimed that fully 60 to 65 per cent of nitrogen excreted is in the form of urea.

Urea may be prepared artificially by the conversion of ammonium cyanate, of which it is claimed to be an isomere, the formula of which is $CO(NH_2)_2$. Its crystals are soluble in water or alcohol, of a saltish taste and possess a neutral action toward litmus paper.

A small part of the protein undergoes katabolism and becomes a part of the cell, but the greater share of it is converted by the liver into urea and discharged as such by the kidney. The latter part of this protein undergoes a general metabolism termed the exogenous, while the former part undergoes the endogenous metabolism. The fact that this process is carried on by the liver may be shown by the following data: After the removal of the liver in certain animals there is the formation of but small amounts of urea and in most cases the process entirely ceases. In degenerative changes of the organ the excretion of urea, if not entirely, then for the most part, is replaced by ammonia.

Urea is formed largely from amino acids such as glycine, leucine and arginine. These bodies are broken up into simpler compounds which again unite, resulting in urea formation. Arginine illustrates this point better than any other amino acid. It is a substance which consists of the urea radicle and ornithine. Ornithine is then acted upon by a special enzyme, arginase, which converts a part of this body into urea, and it is for this reason that larger amounts of urea are excreted than can often be accounted for.

CHAPTER XLVII

STRUCTURE OF THE SKIN

The skin is the covering found over the entire body, and is continuous at the orifices of the body with the mucous membranes which line them. Varying from 1-50 to 1-6 of an inch in thickness, it is thinnest in the eyelids and thickest in the palms of the hands and soles of the feet. The skin varies in its color, depending upon the race and also upon the age and conditions under which the individual lives. In early life it is of a pinkish shade, changing to a yellowish color in old age. In those who are exposed to the elements and live out of doors the color is deepest.

In describing the skin we may divide it into two main divisions; the external layer, false skin or epidermis, and the true skin, cutis vera or dermis.

The epidermis is essentally of epithlial structure, stratified in character, and consists of two layers, the outer or horny layer and the inner or Malpighian layer. Although supplied with nerve fibers, the epidermis is not supplied with blood vessels; however, it has its nutrition supplied by the serum and lymph which reaches it in the intercellular and intracellular channels.

The external horny layer has no subdivisions, but consists of many layers of cells placed one upon the other, and all of the flattened scalelike and non-nucleated variety. These cells are composed largely of keratin, a hard, horny substance, and as they are worn off by constant friction, the surface layers are supplied by those directly below and they in turn by others

below them. The horny layer is constantly being supplied from the superficial layer of the Malpighian strata.

The Malpighian layer is divided into four subdivisions, known from without inward as the stratum lucidum, stratum granulosum, stratum mucosum and the stratum germinativum. It will not be necessary to consider at length their distinctions. Suffice it to say that the lower layer of cells, those in the stratum germinativum, are cylindrical shaped, and it is from them that new cells are constantly being supplied to the depleted layers above. As the cells multiply in the lowest layer of the epidermis they begin a journey toward the surface, changing as they approach it, into a hard, horny mass made so by the acquiring of keratin.

The dermis, or true skin, is found immediately beneath the epidermis, with only a thin, structureless membrane interposed between them known as the basal membrane. The dermis is divided into two layers, an outer or papillary layer and an inner or reticular layer. The dermis, unlike the epidermis, is supplied with blood vessels as well as with nerve fibers.

The papillary layer of the dermis is so called because it discloses upon microscopical examination many papillae projecting their apices toward the surface into the small spaces between the cells of the stratum germinativum. These papillae are formed by upward projections of the underlying connective tissues in which are found many elastic fibers. About 1-100 of an inch in height and 1-200 of an inch in width at the base, these papillae are divided into two groups. The first is known as the vascular group because in the papillae are found rich supplies of capillaries. Those of the second group are not so numerous, known as the nerve papillae. These are so named because found in them are the end organs of the special sense of touch.

The reticular layer of the dermis is so named because of the reticular shape of the interspaces found between the bundles of white fibers. This layer is formed largely of white fibers,

having between them cells, matrix, lymphatics, blood vessels, nerves, hair follicles, suderiferous and sebaceous glands. There is no definite line of demarkation between the papillary layer and the reticular layer and the change of the reticular into the subcutaneous areolar tissue is equally difficult.

APPENDAGES OF THE SKIN

The nails are thickened masses of the stratum lucidum and are found at the tips of the fingers and toes on their dorsal surfaces. Convex on its outer surface, each nail consists of a body, two lateral margins, a free edge and a short edge. The lateral margins and the short edge are inserted into a groove known as the ungual sulcus, and the edges are overlaid with thin projections of the horny layer known as the ungual folds. Just beneath the body of the nails the cutis vera is found, and here as in other parts the surface layer shows masses of papillae. These papillae are arranged in longitudinal folds and are very vascular. The growth of the nail is maintained from this papillary layer beneath the body of the nail and the root and hence it is known as the matrix.

Hairs are considered as appendages of the skin, and upon microscopical examination it is found that they disclose very much the same structure as the skin itself. Varieties of color are found in the hair, differing with different individuals, races, and perhaps in different parts of the body. With the exception of the soles of the feet and the palms of the hands, every part of the body surface is covered with hairs. They differ a great deal as regards their size, being long on the scalp while comparatively short on the dorsal surfaces of the hands. A hair consists of a root, shaft and tip, and is placed with its root in an oblique depression known as the hair follicle.

The hair follicle is merely a long tubule extending either in an oblique or curved course from the surface of the skin, through the various layers and into the subcutaneous areolar tissue, where it ends in a dilated extremity known as the fundus. The wall of the follicle consists of a definite structure resem-

bling, and really a continuation of the reticular layer, the papillary layer and the basal membrane which is adherent to the hair root, and clings to it if the latter is extracted. At the fundus of the follicle is a small papilla, known as the hair papilla, which projects into the hair bulb and from which the hair is developed.

The shaft of the hair upon cross section shows a central medullary substance, an outer cortical substance and outside of this a true cuticle. The medullary substance is composed of cells polyhedral in shape and having between them many air spaces. The cortical substance is composed of fibrous tissue, the fibers of which are very thin and fusiform in shape. Between these fibers are placed pigment granules which give the characteristic color to the hair, and in old age when this color disappears and the hair changes to gray, it is because these pigments are destroyed and in their place are found minute air spaces. The true cuticle of the hair is a single layer of very thin cells, directly in contact with the lining layer of the follicle.

Arrectores pilorum are minute bundles of plain muscle fibers extending from the superficial layers of the horny skin downward and inserted into the lining membranes of the hair follicles, which, it must be remembered, lie obliquely in the skin. When they contract they depress the surface just over where they have their origin, and at the same time raise the follicles to a more perpendicular position and thus elevating the surface of the skin around the point of emission of the hair shaft. This gives rise to the curious condition known as goose skin.

The sebaceous glands are saccular in type, with a main duct leading from the hair follicle into the reticular tissue and at the extremities becoming dilated to form from ten to twenty saccules. These are lined with epithelial cells which possess the power of taking from the lymph and blood which bathe them the fatty substances and to discharge them into the lumen of the gland. This oil is thus carried out to the follicle and thence to the external, serving not only to lubricate the hair, but also to

lubricate the skin. It is thought that these sebaceous glands are squeezed when the arrectores pilorum contract, and in this way their secretion is eliminated.

The sudoriferous or sweat glands are found over practically the entire surface of the body. This with the exception of the glans penis, the prepuce, and the border of the lips. They are more numerous in those parts where excretion takes place in the greatest quantities, as in the axilla. It is computed that in certain parts of the body there are nearly three thousand orifices to the square inch, while on other portions there are only about four hundred to the square inch. It is also computed that there are something over two million of these glands on the surface of the body. Lined with epithelial cells placed upon a basement membrane, these glands are simple tubular in type, extending from the surface of the horny layer to the deep subcutaneous tissues. Lying throughout most of their extent in a spiral or corkscrew course, they are important in carrying away many of the excretions from the body, and it is a peculiar fact that they are present in greater quantities in those areas where hairs are absent.

CHAPTER XLVIII

PERSPIRATION

Invisible perspiration is the expression applied to that degree of excretion from the suderiferous glands which may be evaporated and not gather in droplets on the surface of the skin.

Visible perspiration is the expression used to denote that degree of excretion by the sweat glands which gathers as small droplets on the surface of the skin, and is present only when the sudoriferous glands are functioning more rapidly than their secretions can be evaporated. This visible and invisible perspiration is not entirely dependent upon the activity of the sweat glands. It is affected somewhat by other considerations. If the temperature is high the sweat will be evaporated more quickly and the degree of saturation of the atmosphere determines in part just how fast the moisture will be evaporated.

To state just how much sweat is given off from the body by the sudoriferous glands would be very difficult, because it varies with so many different factors. The degree of work, the temperature, the quality and quantity of foods taken, etc., all have their effect upon the production and as these vary the amount of sweat varies. The sweat varies, however, in inverse proportion to the excretion of urine by the kidneys, that is, when the kidneys are very active the sweat glands are correspondingly inactive, and vice versa. In general, however, it may be said that in the ordinary individual about the same amount of fluid is given off from the skin as is given off from the kidneys in the same length of time.

The control of the amount of sweat is through the nervous system, although not entirely through nerves of secretion. The vaso-motor nerves are concerned also, and it is found in experi-

menting that if the vaso-inhibitory fibers are stimulated there is an increase of activity in the sweat glands, while if the vaso-constrictor fibers are stimulated there is a decreased activity. There are secretory fibers, however, which serve to act in harmony with the vaso-motor fibers.

The sweat varies somewhat in its composition, but in general contains about 98.9 per cent water and 1.1 per cent solids. In the solids we find salts, fats, urea and small quantities of epithelial cells which are constantly being given off from the surface of the body. The sweat is saltish in taste and usually of an acid reaction, although in profuse perspiration it may become neutral or even alkaline.

FUNCTIONS OF THE SKIN

Protective: It is composed of a hard, horny material which withstands ordinary pressure without affecting underlying structures.

Sensation: In the skin are located most of the end organs of the special sense of touch.

Radiation: The skin serves to radiate heat and thus maintain the bodily temperature at the normal.

Respiration: There is a slight exchange of carbon dioxide for oxygen on the surface of the skin.

Secretion: The skin serves to secrete an oily substance by means of the functional activity of the sebaceous glands.

Excretion: It eliminates sweat by means of the sudoriferous glands contained in its structure.

INNATE CONTROL OF THE SKIN AND ITS FUNCTIONS

Upon first thought one might suppose that the skin merely acted as a covering for the body, serving to protect the underlying structures from any slight destructive influences upon the external. When we realize, however, the extent to which Innate utilizes the possibilities latent in its structure, we begin to get an idea of its importance from other standpoints.

Primarily it is true that the skin is of importance in acting as a protection against external force which might injure the soft underlying structures, and here is shown the wonderful adaptive ability which Innate possesses in altering the skin to meet the changed conditions or the variation of conditions in different parts of the body. The skin which covers the palms of the hands and the soles of the feet is devoid of hair and is very thick, due to the fact that these surfaces are constantly coming in contact with external objects which might produce injury if the skin were not thick. This thickness and toughness of the skin in these parts as in all other locations is subject to vast change, depending upon the character of work to which it is subjected. An individual who does manual labor has much thicker, heavier skin on the hands than one who does not. Innate becomes aware by afferent impressions of the necessity for greater protection and immediately deposits greater quantities of keratin in the skin and thickens it as well. The same adaptative ability of Innate is illustrated in the toughness of the skin of the face upon those who are subjected to all kinds of exposure to the elements. Thus here as in other ways we must revert to the controlling influence of Innate in order to explain the changes which occur in the covering of the body.

In the skin are located also many of the end organs of the special sense of touch, because it is with the skin covering the body that most foreign bodies find contact. With their peripheries terminating in these end organs of touch, we have the thousands of sensory nerves all finally converging to the great sensory area of the brain. Innate finds these sensory end organs and sensory nerves of vital importance because it is when she receives impressions over them that she is enabled to produce actions which shall be in harmony with the external conditions. If the finger is brought in contact with a hot stove, Innate interprets the impression received and immediately sends out motor impulses which when expressed take the finger well out of harm's way. So it is that the end organs of the sense of touch are important.

Heat is being generated in the body at all times. Oxidation is being carried on continually and thus every organ is producing its quota of heat. Some of the organs, especially the active glands and muscles of the body, produce more heat than others, and they also produce different amounts of heat at different times. Innate controls the skin in such a way that the radiation of heat shall be in proportion to its production and thus the body temperature remain at the normal. If the individual is violently exercising oxidation is taking place more rapidly and heat is being produced faster. At this time radiation is also markedly increased by Innate in order to maintain the normal temperature. On the other hand if, as during sleep, oxidation is occurring slowly, the radiation is also taking place more slowly.

Innate has masterfully constructed the body so that every individual organ will be supplied with those substances which are necessary in its maintenance. In the case of the skin the epidermis is not supplied with blood vessels and thus cannot depend upon them for oxygen. It is for this reason that Innate exchanges carbon dioxide in the epidermis for oxygen on the outside. This is called tissue respiration and is an action controlled entirely by Innate Intelligence.

During development Innate has placed in the skin small sebaceous glands or oil glands which serve to secrete an oily substance for the lubrication of the surface of the body. If it were not for the presence of this oil to give body to the cells they would become hard, dry and scaly, and would be unable to withstand the friction to which all parts of the body are more or less subject. This is illustrated in cases of dry eczema, where because of nerve impingements, Innate is unable to supply the skin with oil, and because of this fact very little friction can be withstood.

Sudoriferous glands are also found in the skin, and it is through them that Innate exercises the power of expelling from the body materials which are no longer of value. In this respect

the sweat glands perform a function similar to that of the kidneys. This action of the sweat glands is directly under the control of Innate Intelligence, which has the power of altering the amount of perspiration expelled as the varying conditions arise.

SECTION X

CHAPTER XLIX

VOICE

In studying the subject of voice we must consider not only the cause of the production of sound, but how the sounds are altered in pitch and how articulation is brought about by the modification of the sounds by the tongue, lips and teeth. The important consideration, however, is where the tone is first produced, and the study of this mechanism will be undertaken first.

The larynx is commonly known as the voice box and is placed at the upper end of the trachea, its base resting upon the trachea and its upper border lying next to the root of the tongue. Its posterior wall forms part of the anterior wall of the pharynx, and normally it lies opposite the bodies of the cervical vertebrae from the fourth to the sixth inclusive. It is placed somewhat higher in the female than in the male and higher in the infant than in either the male or female. At puberty the larynx of the male undergoes a marked change, becoming enlarged in all its parts. The enlargement of the thyroid cartilage is perhaps more noticeable than of any other part, because of the great prominence which it assumes on the anterior surface of the neck. Here it forms the pomum Adami, or Adam's apple, which in men is so prominent. On either side of the larynx lie the great vessels of the neck which supply and drain the head and neck.

The larynx is composed of nine cartilages which are connected one with another by means of ligaments. Some of these

cartilages are arranged in pairs, while others are present singly. Those which are found in pairs are the two arytenoid cartilages, the two cornicula laryngis cartilages, and the two cuneiform cartilages. Those which are found singly are the thyroid, cricoid and the epiglottis. It will be necessary before a clear understanding can be gained of the manner in which the larynx functions, that we enter into detail regarding the shape and comparative sizes of these cartilages, how they are placed in relation to one another and the manner in which their actions are controlled.

The thyroid cartilage is the largest one of the cartilages of the larynx and its shape may be favorably compared to that of a shield. There are two alae or lateral wings, and extending upward from the posterior borders of these two alae we find projections which are known as the superior cornu. Extending down from the posterior borders are also two projections which are known as inferior cornu. At the anterior where the two lateral wings meet is formed a pronounced projection which is known as the Pomum Adami. This is especially prominent at the superior border of the thyroid cartilage, so that in viewing the entire structure from above the two wings seem to come together to form a V. At the inferior there is no such acute angle and the two wings meet to form the anterior border of an oval opening into the trachea. During infancy this point of juncture of the two alae is formed by a strip of cartilage. During puberty this soft material is replaced by true bone, which not only fills the space formerly occupied by the cartilage, but extends further toward the anterior. This largest of the laryngeal cartilages forms the anterior and lateral walls of the larynx, articulating at the apex of the V formed by the alae and at the superior border with the epiglottis, while the inferior cornu articulate with facets on the outer surface and lateral to the quadrate portion of the cricoid cartilage.

The cricoid cartilage is the second largest one of the cartilages of the larynx. It is situated at the inferior of this organ,

forming the entire lower border, which articulates with the trachea and a large part of the posterior wall. In the shape of a signet ring, it is divided into two main divisions known as the quadrate portion and the arch. The quadrate portion is the thickened or signet part of the ring and is placed toward the posterior, while the arch or narrow band of the ring is placed so that it forms the entire lower border, and forms with the alae of the thyroid cartilage the sides and the anterior wall of the trachea. The cricoid cartilage presents on the lateral and outer border of its quadrate portion two articulating facets for the inferior cornue of the thyroid, and this is the only means of connection between the thyroid and cricoid cartilages. This should be borne in mind, because it is upon this feature that the change in the pitch of a tone must be based. On the upper border of the quadrate portion on either side of the median line are two articulating facets for the articulating of the bases of the arytenoid cartilages.

The epiglottis is a single cartilage of the larynx, which serves as a covering or lid to close it at its upper opening. The epiglottis is a leaf-shaped cartilage with the stem of the leaf attached at the anterior into the angle between the two alae, while the borders follow the upper border of the superior laryngeal opening and the tip is placed at the posterior of this opening.

The arytenoid cartilages are two in number and are pyramidal in shape. They consist of a base which articulates with the facets on the upper border of the cricoid cartilage, an apex which projects toward the superior from these articulating facets and a body composed of three surfaces.

The cornicula laryngeal cartilages (cartilages of Santorini) are two in number, conical in shape and situated at the apices of the two arytenoid cartilages. As the apices of the arytenoid cartilages curve backward, these conical cartilages serve to prolong that backward extension still further.

The cuniform cartilages (cartilages of Wristberg) are two narrow, thin cartilages lying in the aryteno-epiglottic membrane,

one on either side, and just anterior to the tips of the arytenoid cartilages.

The inner surface of the larynx presents an irregularly shaped cavity, the irregularities produced by the presence of ligaments and muscles which project into it beyond the inner surface of the walls. The larynx is divided into two main divisions by the presence of the true vocal cords which are two in number, one situated on the right side, the other on the left. These are sometimes called the inferior thyro arytenoid ligaments, because they are composed of yellow elastic tissue and extend from the grove at the anterior and inner surface of the thyroid cartilage to their posterior attachments on the vocal processes of the arytenoid cartilages. Filling in the space between each of these vocal cords and the wall of its side is interposed a thick mass of connective tissue and muscle, overlaid with a layer of stratified epithelial membrane. It can readily be seen then that there is a space left only between the two vocal cords, and this is known as the rima glottis.

Just above the true vocal cords are two bands of thin connective tissue covered also with mucous membrane, which extend in the same direction as do the true vocal cords. These are sometimes called the superior thyro arytenoid ligaments, but are not classed with the true vocal cords because they are not concerned in the production of voice.

The ventricles of the larynx are two in number and are the spaces formed on either side of the voice box, between the superior and inferior vocal cords.

The entire inner surface of the larynx is lined with mucous membrane. This is in turn lined with epithelial tissue which is of two types. Ciliated epithelium is found lining the entire cavity, with the exception of that region over the vocal cords and a part of the surface of the epiglottis, in which places the stratified variety exists.

The muscles of the larynx may be divided into two divisions, those which serve to connect the larynx to surrounding struc-

tures, and those which are found extending from one cartilage to another. The former are classed as extrinsic muscles and the latter as intrinsic muscles. It is with the intrinsic muscles that we are principally concerned at this time, because it is by means of them that we are enabled to produce different degrees of tone and pitch.

The intrinsic muscles of the larynx are:

Crico-thyroid.
Thyro-arytenoid.
Posterior crico-arytenoid.
Lateral crico-arytenoid.
Arytenoideus.

The crico-thyroid is a double muscle, one on each side, extending from the upper border of the arch of the cricoid cartilage on its lateral margin upward to its point of termination in the inferior border of the thyroid cartilage and the anterior border of its inferior cornu. Remembering now that the only means of articulation between the thyroid and the cricoid cartilages is that formed by the inferior cornu of the former with the lateral facets of the latter, we may readily see what would occur if this muscle were contracted. The anterior arch of the cricoid would be drawn upward and at the same time the posterior quadrate portion, where the arytenoids are attached, would be drawn toward the posterior. The true vocal cords have their posterior point of attachment on the vocal process of the arytenoid, and as the arytenoid is carried with the quadrate portion of the cricoid cartilage, it can readily be seen that a contraction of this muscle would stretch the elastic vocal cords.

The thyro-arytenoid is an intrinsic muscle of the larynx, which, as the name implies, extends from the thyroid cartilage to the arytenoid cartilage. There are two of these muscles, one on either side of the larnyx, and we may say that normally all these double muscles work in harmony with their mates. For the sake of convenience we will describe just one of them and remember that its description applies equally to the other. It is

divided into two divisions, an inner and an outer. The former has two sets of fibers, one arising from the angle of the thyroid cartilage on its inner surface, near the inferior border, and extending from here toward the posterior, where it is inserted into the outer border of the arytenoid cartilage. This set of fibers is parallel to the true vocal cords and lies just outside of them. The other set arises from the vocal process of the arytenoid cartilage, and proceeding toward the anterior, inserts itself into the structure of the cord along its course. The outer division consists of fibers which arise from the thyroid cartilage and extend from here backward to be inserted into the vocal process of the arytenoid cartilage. Here also we have another set of fibers which arises from the crico-thyroid membrane and extends from here upward and backward, some of them being inserted into the arytenoid cartilage and some of them following upward and terminating in the false vocal cords. We can readily see that in general the fibers of the thyro-arytenoid muscle extend from the thyroid cartilage at the anterior to the arytenoid cartilage at the posterior. When this muscle contracts it will serve to draw the arytenoid cartilage, attached to the quadrate portion of the cricoid, upward and toward the anterior, thus decreasing the distance between the attachments of the true vocal cords.

The posterior crico-arytenoids form also a pair of muscles, one of which is found on either side of the larynx. It arises from the posterior surface of the quadrate portion of the cricoid cartilage, and extends from here to its point of insertion in the outer border of the base of the arytenoid cartilage. By its contraction it serves to rotate the arytenoid cartilage so that the vocal process to which is attached the posterior termination of the vocal cord turns outward, and thus, when the two acting in unison, separate these two processes from one another.

Lateral crico-arytenoid muscles are two in number, one on each side of the larynx. The muscle on either side arises from the anterior border of the quadrate portion of the cricoid cartilage and extends from here to the superior, where it is inserted

into the posterior surface of the base of the arytenoid cartilage anterior to the posterior crico-arytenoid. By its contraction it serves to rotate the vocal process of the arytenoid cartilage inward and thus, when the two muscles act in unison, approximating them.

The arytenoideus is the only one of the intrinsic muscles of the larynx which is a single muscle. Its fibers progress in three distinct groups. The anterior fibers are arranged transversely from one arytenoid cartilage to its fellow, while the two posterior groups are intermingled, and extend from the base of the arytenoids to the apices of the arytenoids on the opposite side. Upon examination from the posterior then, these fibers by their arrangement form a cross. The arytenoideus is accessory to the lateral crico-arytenoid muscles in that it serves also to approximate the vocal processes of the arytenoid cartilages.

FUNCTION OF THE LARYNX.

Having considered thoroughly the courses which these muscles pursue, we are in a position to consider the function of each in the important action of voice production.

The crico-arytenoid draws the points of termination of the vocal cords apart, thus lengthening them, and when a column of air passes over them a tone of high pitch is produced.

The thyro-arytenoid draws the points of origin and insertion closer together, thus relaxing the vocal cords and producing a lower pitch when a sound is made. These two muscles just mentioned are the only muscles of the larynx which have to do with the changing of pitch in tone. The other three are all concerned in the regulating of the size of the chink between the vocal cords.

The posterior crico-arytenoid upon contraction serves to widen the aperture between the vocal cords because they are attached at their posterior to the arytenoids and when these are drawn apart the chink must of necessity be widened.

The lateral crico-arytenoids rotate the arytenoids inward and thus draw the vocal processes of these two cartilages into

proximity. In this manner the rima glottidis is narrowed and perhaps closed.

The arytenoideus by its contraction draws the two arytenoid cartilages into proximity, thus acting as an accessory to the lateral crico-arytenoids.

It is during breathing when no vocalization is taking place that the chink is wide open. This is due to the action of the posterior crico-arytenoids, so that in breathing they are always in a state of contraction. If deep inspirations are taken these muscles contract even more and the aperture is widened even further.

When Innate produces a sound of the voice, she narrows the rima glottidis, and the pitch of the tone thus produced by the column of air passing over the vocal cords she controls not by the proximity of the vocal cords, but by the degree of tension which she places upon them by sending motor impulses to the crico-thyroid or the thyro-arytenoideus. The height to which one may vocalize then, is determined by the degree of tension which Innate is able to express in the vocal cords.

There are a number of factors which are utilized in the production of the human voice, but scientists thus far have only gone so far as to say that it is the column of vibrating air passing over the vocal cords. This is true, but there is a mass of detail behind this statement which must be considered to gain a knowledge as to the real and ultimate cause. In the first place, no tone can be produced unless there is the passage of air over the vocal cords, and this cannot be accomplished without the act of respiration. All the muscles of respiration are then concerned in the production of tone. Innate sends out motor impulses to the inspiratory muscles and as they contract, enlarging the size of the thorax, air passes in through the air passages to fill the partial vacuum which is thus created. The natural elasticity of the thorax then asserts itself, aided perhaps by the contraction of the expiratory muscles, and this air is expelled. Here again

we must consider the expression of Innate motor impulses as the real cause for the expulsion of this air.

It is at this time that Innate expresses herself in the production of tone. She sends down motor impulses to the crico-thyroid muscles if she intends to produce a high pitch, and to the thyro-arytenoid muscles if she intends to produce a low pitch. Thus, by causing these muscles to contract she is able to produce a tension or a relaxation of the vocal cords. Further than this she sends inhibitory impulses to the posterior crico-arytenoid muscles and motor impulses to the lateral crico-arytenoid, producing in the former a relaxation and in the latter a contraction. By so doing she draws the vocal cords closer together, that the column of air may vibrate in passing the rima glottidis.

Because of this expression of Innate, each part of which is an intricate process in itself, but every part absolutely coördinated with every other part, we have the normal production of tone.

The process, however, is not as yet complete, because tone which merely had its pitch altered would be inadequate to express our thoughts. This tone must be altered by the action of the tongue, palate, etc., and these changes are all because of the expression of Innate in the muscle fibers which control these organs.

SECTION XI

SPECIAL SENSES

CHAPTER L

SUPERFICIAL AND DEEP SENSATIONS

Formerly it was the custom to group all classes of cutaneous sensations, such as heat, cold, touch, pressure and pain under the common heading of touch sense. Later investigations have, however, led to the conclusion that these varieties should be grouped under a different name, so we have employed the expression cutaneous and internal sensation, or superficial and deep sensations.

Under this main classification there are many subdivisions, but those associated with the cutaneous sensation may be divided into four. First touch, indicated by the sensation produced when the skin is touched lightly. Second pain, when the pressure is increased until discomfort occurs and the more modified sensation merges into the more severe. Third heat, when a sensation of increased temperature is produced. Fourth cold, when a sensation of decreased temperature is produced.

The sensation of pressure is produced by vibrations upon end organs situated in the deeper structures and not in the skin itself. Upon minute examination of the various areas of the skin we discover that there are certain minute spots which are susceptible to the vibrations of heat, certain of them to cold, some to touch, etc. This has led to the use of the terms heat spots, cold spots, touch spots, etc.

It has long been a matter of conjecture as to whether or not

these different sensations were the result of different impulses carried over different nerve fibers or whether the result of different impulses carried over one and the same fiber. It is well to note here that when one touch spot is stimulated it gives rise to the sensation of touch. Now another touch spot is stimulated and still the sensation is one of touch. Now a point between the two may be stimulated by the same excitatory force and the result is not a sensation of touch, but one of itching perhaps or tickling. This supports the chiropractic idea that different kinds of nerve fibers transmit mental impulses which are characteristic of themselves. This is also demonstrated in the study of the eye. When the eye is struck the sensation is one of light, showing that no matter what the vibration at the end of a nerve is, the interpretation at the center of that particular nerve is always the same, because normally that particular nerve fiber receives only that kind of impressions which, when interpreted, should give rise to a particular sensation.

TOUCH

Around the follicle of each hair on the surface of the body is a minute plexus of non-medullated nerve fibers. These constitute the terminations, which when subjected to vibrations give rise to the sensation of touch. In those parts of the body where the hairs and follicles are not present, as upon the palms of the hands, the places of these plexuses are taken by the touch corpuscles of Meissner. It is contended that the skin just at the mouth of the follicle and on the side away from which the hair bends, is the most sensitive to touch. The sensation of touch is more acute in some individuals than in others, as it is also more acute in some parts of the body than in others. This partly depends upon the fact that some parts of the body contain a greater number of touch spots than others; also upon the condition of the skin over the part receiving vibrations, and upon the degree of mental concentration applied to the receiving, and interpretation of impressions due to these vibrations. This is amply demonstrated in the

teaching of the blind to see with their fingers. The sense of touch here is more acute than in others who are blessed with all the senses, not because the blind individual has more touch corpuscles or more touch spots on his body, but because his training has all been along the line of concentrating his entire attention upon the receiving and correctly interpreting the impressions.

There are very few of the deep structures of the body which are sensitive to vibrations of touch. We are not aware by this sense of the presence of food in the alimentary canal, nor are we aware of the presence of urine in the kidney.

In the case of touch there is a vibration which comes in contact with the end cells of the sense of touch or the minute nerve plexuses which are capable of responding to these vibrations. These areas are scattered all over the body and an external object coming in contact with the surface of the skin over these areas is sufficient to produce vibrations. Touch, however, is more than mere knowledge that some object is in contact with the flesh. We are aware of the character of the article touched, of its roughness or smoothness, of its hardness or softness, and these sensations are not because of different impressions sent along the afferent nerves of touch, but because the interpretation of Innate Intelligence immediately acquaints us with these characters. In brief the touch corpuscles and nerve filaments which receive the vibrations, alone would be quite unable to determine, not only the character of the articles, but even the fact that they were touched. It is to the Innate Intelligence that is left the assimilating and tabulating of this information, and all these interpretations constitute a perception.

HEAT AND COLD

The sensitiveness of the various parts of the body to degrees of temperature is necessarily one of comparative values. In order to state that a certain substance is hot we must have something to compare it with, and in the case of cold, the same is true. If the finger is held for some time in water at ice cold temperature

and is then removed and placed in water of ten degrees centigrade, the latter seems warm, while if the finger had been plunged into it first the sensation would have been one of cold. Temperatures are, however, judged usually by the temperature of the skin, and if a substance is higher in temperature it is said to be lukewarm, warm or hot, depending upon degree. If lower, it is said to be cool, or cold, also depending upon degree. The heat areas or warm spots on the surface of the body are about 30,000, while the cold spots are about 250,000. In the sensation of cold and heat, as in that of touch, there seems to be very little sensibility in the internal organs, and in the alimentary canal below the oesophagus a comparatively high or low temperature must be reached before there is a sensation.

Temperature is a term which is capable of wide interpretation as to degree, because everything is comparative. For this reason we measure it by the thermometer, which contains mercury, which expands or contracts, dependent upon the degree of heat or cold. The nerves which are utilized by Innate to carry impressions of temperature from the peripheries to the thermal center in the brain are afferent nerves, no different in structure than other afferent nerves, but endowed by Innate Intelligence with the peculiar power of responding to vibrations of heat or cold. It is a mistake to assume that normal degrees of temperature are not noted by Innate, merely because we are educationally unaware of them. The fact is that continually there are being carried to the brain from the end organs impressions of temperature, and Innate is continually aware of these degrees. If, however, the temperature is approximately that of the body, we are not educationally aware of that temperature, because there is no necessity for such knowledge. On the reverse, if the temperature is extremely high or extremely low, we are educationally aware of that fact because there is a necessity for that knowledge. The vibrations are no stronger in these cases, but the interpretation is more noticeable because it is something to which we educationally

are not accustomed. If an individual who is not used to braving the elements remains out of doors in zero weather he will feel the cold much more keenly than one who has been accustomed to this weather continually.

PAIN

This is a form of sensation, not only cutaneous, but also involving the deeper structures. The question has been raised as to whether pain is not due to an increase in the intensity of the touch vibrations on the end nerves of touch. This is not the case, because pain is a feature which is present in the deeper structures as well as on the surface. It is more reasonable to assume that the sensation of pain is the result of a vibration on the ending of a pain fiber. True it is, that on the surface of the skin there are more pain fibers than in the deeper structures. In operations where no anesthetic is administered, the greatest pain is experienced when the incision is made through the skin. Pain, the result of excessive contractions or distentions in the viscera, is merely the mental interpretation of the abnormal condition which is existing there and only occurs when a degree of contraction or distention has been reached beyond the ordinary.

Pain is not only interesting from a physiological standpoint but it is important as a practical factor. We may truly say that this type of sensation is the great indicator of abnormality existing in the body and serves to lead the chiropractor to the effect of the lack or excess of mental impulse supply. In the case of trauma it is merely the expression of danger, and in many instances serves to convey a warning to Innate that preventative measures may be taken.

PRESSURE

Pressure is classed as a sensation, but is not to be associated with the cutaneous sensations; rather with those of the deeper structures. The Pacinian corpuscles are the specific end organs of the sense of pressure and they are situated in the subcutaneous tissues, and in many of the visceral organs. Pressure, also, as

heat and cold, may be said to produce a sensation only when associated with difference in degree. We are all surrounded by an atmospheric pressure of something like fourteen pounds to the square inch over our entire bodies. We are, however, completely unaware of this pressure because it exists in all parts and in all directions. If the palm of the hand is placed over the opening of a vacuum bottle and the air in the bottle removed, the pressure here is greatly decreased. We immediately feel acutely the effect of the pressure on that part of the hand exposed to the external air. If a pressure of the blunt end of a pencil is applied to a spot on the surface of the skin, we feel the pressure because it is greater than that applied to other parts of the body. If all parts of the body then are subjected to the same pressure, both inside and outside, there is no sensation of pressure.

LOCALIZATION

This is the term applied to the ability of the individual to gain a knowledge of the exact part of the body where sensory vibrations have been applied. Thus when a certain part of the body, say the tip of the finger, has been subject to contact with the tip of a pencil, we are aware which finger has been touched and with a greater or less degree of certainty what part of the finger. This is due to the fact that the nerve fibers from various parts of the body end centrally in certain areas and the brain associates the peripheral vibrations with the central expression of those vibrations. This is true with the exception that instead of using the term brain we would suggest the expression Innate Intelligence. The brain is a mass of chemicals, with its power of interpretation controlled entirely by the presence of Innate. It would be better then to say that Innate receives the afferent impulses and after interpreting them becomes aware of the part of the body from when they originated. The accuracy of localization is more acute in some parts of the body than others. Thus at the tip of the tongue, if the points of compasses are touched to the mucous membrane, the sensation of two points is clearly

interpreted, even if the points are only 1/12 of an inch apart. If on the other hand one or more points are applied to the back, even if they are as much as two inches apart, the individual is unable to state how many points are applied or just where they are located.

MUSCULAR SENSATION

Having taken up in detail many kinds of sensory interpretations, we now consider one which has to do with the knowledge of the muscular contractions which occur in the voluntary muscles. There is no doubt but that we are aware of the contraction of the skeletal muscles and in degree the extent to which they are contracted. Investigations tending to establish the course of the afferent nerves which supply impulses for this sensation have been made, and lead to the conclusion that the nerves enter the spinal cord through the posterior roots, but where their central termination is remains still a matter of conjecture. Microscopical examination of the muscle structure has disclosed the presence of small, spindle shaped masses of striated muscle, surrounded by a capsule of connective tissue, which is pierced by the nerve fiber and in the substance of which the fiber terminates. It is probable that in the contracting of the muscle these spindle shaped bodies are compressed and the peripheries of the sensory nerves thus subjected to vibrations. Innate is then able to interpret the impressions dependent on their severity, and thus become aware of the degree of contraction. The Pacinian corpuscles are also vitally concerned in this process, as it is found that by removal of them the muscular sensation is greatly impaired.

HUNGER AND THIRST SENSATIONS

These are inserted at this time, rather to call the reader's attention to their presence than to offer an explanation of their existence. This much may be said, however. The sensation of hunger is due in large measure to two factors. First, to the emptiness of the stomach and intestines, second to the general

feelings of weakness and depression. The emptiness of the stomach, in connection with the gastric contractions, gives rise in some manner to the pangs of hunger, but what the apparatus is which produces this sensation is not known. Appetite is closely associated with hunger and yet is distinct from it. The former takes into account especially the pleasure in taking food, and the anticipation of this pleasure, while the latter includes especially the physical requirement for food. Hunger may exist and still the appetite for foods be absent.

Thirst is the appetite of the individual for water, and is especially due to a dryness of the mucous membrane of the mouth and pharynx. This dryness may be due to a number of causes; perhaps to the inhaling of dust; perhaps to the kinds of food swallowed; or after water has been withheld for a considerable time to the deficiency of it in the tissues of the body.

In the consideration of the various kinds of sensations we have mentioned two kinds of corpuscles which are concerned, in that they are found at the terminations of the sensory nerves. These are the Pacinian corpuscles and the touch corpuscles.

PACINIAN CORPUSCLES

These small bodies (1/12 inch in length) are oval in shape and situated deeply in the subcutaneous tissue. They are also found in some of the glands of the body, in the tendons, and synovial membranes of joints. Each corpuscle is made up of concentric layers of connective tissue, each one of which is lined with epithelium of the pavement variety. The nerve fiber enters the outer membrane, losing its medullated sheath and progresses to the very center of the body. Sometimes two of these nerve fibers terminate in the center of one corpuscle and sometimes a fiber passes directly through one corpuscle to terminate in another. These corpuscles are thought to be especially concerned in the sensations of pressure and in muscular sensations.

TOUCH CORPUSCLES

These are very minute bodies about 1/300 of an inch in length, and 1/800 of an inch in breadth. They are found widely distributed in the fingers and toes, but are also placed in greater or less numbers over the entire surface of the palms and soles. Located in the papillae of the papillary layer in the true skin, they are more superficial than the Pacinian corpuscles. The nerve fiber upon entering one of these corpuscles loses its medullated covering and terminates in its substance. These corpuscles are composed of connective tissue surrounded by a capsule.

CHAPTER LI

TASTE

In the consideration of the special sense of taste, notice must be first taken of the structure of the mucous membrane of the tongue and other parts of the oral cavity where the end cells of the sense of taste are found.

Broadly speaking, we may say that the tongue is the end organ of the sense of taste, and as the soluble substances taken into the mouth are the producers of vibrations which, as impulses, traverse the afferent gustatory nerves, we must look upon the surface of this important organ for the end cells. We find them in the taste buds, minute organs which are found especially in the walls of the circumvallate papillae and the fungiform papillae.

There are four kinds of papillae in the mucous membrane of the tongue: the circumvallate, fungiform, conical and filiform.

CIRCUMVALLATE PAPILLAE

These are the largest papillae on the mucous membrane, although the least in number. They are arranged in the shape of the letter V with the apex of the angle toward the posterior at the foramen caecum, the arms pointing laterally and toward the anterior. Each one of these arms is formed by five to seven of the papillae. In structure these minute organs are formed principally of an underlying connective tissue, overlaid with epithelial tissue, while in shape each may be compared to a cone with the apex cut off, and a depression on its upper surface. About 1/12 of an inch in diameter, it is placed with its base in a little cup-like depression, so that the cross-section appears like a central papilla surrounded by a ditch or moat. It is in the wall of this ditch

and in the epithelium of the papilla itself that we find the taste buds thickly distributed.

FUNGIFORM PAPILLAE

These papillae are so named because in shape they resemble a puff-ball fungus. Here the main bulk is formed by the underlying connective tissue, which all over the surface of the papilla is seen to cast itself up into little elevations known as secondary papillae. All this structure is overlaid with the characteristic epithelial tissue, in which are found many taste buds. These small organs are found on the margins and tip of the tongue.

CONICAL AND FILIFORM PAPILLAE

These papillae are so named because of their shapes, some of them having one apex (conical), while some of them are possessed of several (filiform). They are much more numerous than the other two kinds, being found covering the entire anterior two-thirds of the dorsum, but relatively unimportant in the sense of taste. Very few, if any, taste buds are found in them, but they are thought to be the special end organs of the tactile sensation on the tongue.

TASTE BUDS

These are found especially on the dorsum of the tongue, and very thickly placed over the circumvallate papillae, although some of them may be demonstrated on the soft palate, pharynx, and perhaps other of the surrounding soft parts. They are shaped like a cantaloupe, and have for description supporting cells, gustatory cells, gustatory pores and gustatory hairs.

The supporting cells surround the outer wall of the bud, and may be favorably compared to the staves of a barrel, or the individual sections of the wall of a cantaloupe. On the inside of the structure, forming the core, are the gustatory cells, spindle shaped and extending from one end to the other. The entire bud is sunk in the epithelial tissue, and the small opening from the proximal end to the surface is known as the gustatory pore. Projecting into

this gustatory pore are thin extensions of protoplasm from each of the gustatory cells and these are known as the gustatory hairs. It is at the distal extremities that the fibers of the nerves of special sense of taste enter and end in arborizations around the gustatory cells. These nerves are the glosso-pharyngeal and the lingual which supply the posterior and the anterior portions of the tongue respectively.

In order that a substance may be tasted it is necessary that it must be in soluble form, and chemists have made an effort to determine just what chemical elements produced the peculiar tastes. Very little progress has been made along this line, although it has been definitely established that tastes may be grouped under four main heads: sweet, acid, bitter and saline. All sensations of taste then can be grouped under one of these four heads or perhaps as a combination of two or more.

CONCLUSION

Taste is the term applied to the interpretation in the mind of impressions received from those nerve fibers which have their peripheries terminating in the taste buds of the oral mucous membrane.

Here it is true that the various structures, such as the taste buds, the mucous membrane, the afferent gustatory nerves, are necessities, but if these alone existed there could be no sensation of taste. There must be resident a mind which, acting through the brain, places upon the impressions received an interpretation, and thus a perception is formed. It must not be imagined that other conditions in the body do not influence this interpretation because always Innate considers the body as a whole and never the unit as an independent part of the body. The interpretation which the Innate Intelligence in one body makes of the impressions produced when acid comes in contact with the taste buds is pleasurable, while the interpretation made by the Innate of another individual is distasteful. This is not because of a difference in the method of interpretation, but rather to the ability of Innate

to never lose sight of the mass in dealing with the unit. In the body where acid produced a distasteful sensation Innate realized that acid was not needed in the body, and in fact might be harmful. In the other case, however, there undoubtedly was a need for the acid and so the pleasurable sensation resulted.

CHAPTER LII

SMELL

The end cells of the sense of smell are found in the olfactory portion of the mucous membrane of the nasal fossae. This portion of the mucous membrane is found in the upper part of the fossa, midway between the anterior and posterior nares, extending down on the outer wall as far as the superior turbinated bone, and down the septum one-third of its extent. This is sometimes called the Schneiderian membrane and all the rest of the mucous membrane which lines the nasal fossa is known as the respiratory membrane.

The cells which are found in the olfactory portion are known as the supporting and the olfactory cells, the former serving as supports, and the latter being found between them and held in position by them. The supporting cells are columnar in shape, joined with one another at their bases, and with no cilia at the proximal extremities. The olfactory cells are found to contain large nuclei around which is a thin film of protoplasm and projecting from either end, one toward the surface and one toward the underlying basement membrane, are two extensions of protoplasm. The one which projects toward the surface is surmounted by a cilium, which is known as the olfactory hair, and this is the portion of the cell which is directly affected by the various gases which enter the nasal fossae. The extension which proceeds toward the basement membrane pierces this membrane, passes through the openings of the cribiform plate and ends in the olfactory bulb, an outgrowth of the brain.

In the study of the sense of smell notice should be taken of the fact that the majority of sensations of smell are the result of

gaseous substances coming in contact with the mucous membrane of the nose. It should not, however, be supposed that this is the only method by which these sensations may be produced. If certain substances are held in solution and the solution forced into the nasal fossae, sensations of smell may be detected. In the appreciation of various smells, the substance which is the cause of the sensation is brought in contact with the olfactory cells, and produces an impression which is carried from here to the center of smell. Here an interpretation is made and the result is the sensation of a certain odor.

Smell and taste are intimately associated with one another, because they are both senses resulting from chemical agents (sight and sound are senses which result from physical agents) and often act in unison. Thus the taste and smell of an orange are intimately associated, because at the time of partaking of this fruit sensations of smell and taste are both received.

The nerve of the special sense of smell is the olfactory nerve, although it is not truly composed of a trunk ensheathed as are the other cranial nerves. Rather, it is composed of many filaments entering by about twenty openings through the horizontal plate of the ethmoid bone into the nasal fossa and terminating in the olfactory cells.

In the consideration of the sense of smell we should not lose sight of the fact that it is essentially a question dealing with the interpreting of the various impressions which result from the vibrations which come in contact with the olfactory mucous membrane.

The sense of smell is not localized in the nose any more than the sense of taste is in the mouth or the sense of touch is in the fingers. These are the locations where the peripheries of the nerves which are endowed with the ability to receive these peculiar vibrations, are placed. The interpretation of the impressions is in the brain and here it is that we are made aware of the various odors.

CHAPTER LIII

STRUCTURE OF THE EAR

The sense of hearing is that special sense which is the result of impressions carried from the periphery to the center of the auditory nerve, where they are interpreted by Innate Intelligence.

Anatomically the ear is divided into three divisions known as the external ear, middle ear and the internal ear. They will here be considered in order.

EXTERNAL EAR

This portion of the ear is divided into two divisions, the pinna and the external auditory meatus.

The pinna is that shell-like portion which is composed of a framework of cartilage overlaid with softer connective tissue, and covered entirely with integument. For description we have:

Helix. Ridge forming the upper and posterior border of the pinna.

Anti-helix. Forming the upper and posterior border of the concha.

Scaphoid fossa. The depression between the helix and anti-helix.

Darwinian tubercle. Raised elevation at the upper and posterior angle of the helix.

Crura of anti-helix. Two limbs which form the anterior termination of the anti-helix.

Fossa triangularis. Triangular depression between the crura of the anti-helix.

Crus of the helix. The anterior termination of the helix,

which serves to divide the concha into the cavum concha and the cymba concha.

Concha. The great central depression of the pinna which leads to the opening of the external auditory meatus.

Cavum concha. The lower and larger division of the concha formed by the crus of the helix.

Cymba concha. The upper and smaller division of the concha formed by the crus of the helix.

Tragus. The projecting mass of cartilage which extends from the anterior border of the external auditory meatus over the opening of the canal.

Anti-tragus. The projection of cartilage at the lower border of the anti-helix which extends over the cavum concha.

Lobe. The mass of soft connective tissue which forms the lower portion of the pinna.

The external auditory meatus is a canal about one and one-quarter inches in length, which extends from its external opening in the concha to its internal termination in the petrous portion of the temporal bone where a membrane is stretched across its lumen completely occluding it. This membrane marks the inner termination of the external auditory meatus, and is the line of division between the external and the middle ear. The canal proceeds inward in the form of the letter S and is lined with a continuation of the external integument. This integument has opening on its surface the ducts of numerous underlying glands, resembling in structure the sweat glands, and secreting the ear wax. They are known as the ceruminous glands of the external auditory canal.

THE MIDDLE EAR

This division of the ear is found within the substance of the petrous portion of the temporal bone, merely as a cavity and is often called the ear drum or tympanum. Its walls are formed of bone except in a few small areas where there are openings in the bone which are covered with membrane. There are in the

posterior wall of the middle ear a number of small openings which communicate with a mass of spongy bone tissue in the mastoid portion of the temporal bone. These openings and the sponge-like bone form the mastoid cells. Opening from the anterior wall of the middle ear there is an open canal which is the only means by which there is a communication with the external. This canal is called the eustachian tube, and extends from the naso-pharynx to the cavity of the tympanum, one to each ear. Lining the eustachian tube and the middle ear is a continuation of the mucous membrane of the pharynx.

The membrana tympani is the membrane which is stretched across the inner extremity of the external auditory meatus, and serves as a point of division between the external and middle ear. The fibers of which this membrane is formed are of the circular and radial types, and in it is inserted the handle or long process of the malleolus.

The ossicles of the middle ear are three in number, known as the malleolus, incus and stapes. These are the three smallest bones in the body, and are commonly known as the hammer, anvil and stirrup bones, because of their resemblance to these three implements. The malleolus is the hammer shaped bone, and has a long process known as the handle, which is inserted into the membrana tympani. At the other extremity of this small bone is a convex portion known as the head, and this articulates with a depression in the body of the incus. The incus has two processes, one long and the other short, and while the short process articulates with the wall of the middle ear, the long one extends toward the inner wall of this cavity and there articulates with the head of the stapes. The stapes shaped like a stirrup, consists of a head which is in articulation with the long process of the incus, and a base which fits into the membrane covering the fenestra ovalis. Thus it can readily be seen that these three ossicles of the ear form a continuous chain from the membrana tympani to the membrane covering the fenestra ovalis.

THE INNER EAR

This is the third division of the ear and is located in the petrous portion of the temporal bone, just internal to the middle ear, which in turn is just internal to the external auditory meatus of the external ear. The inner ear is, as the middle ear, merely a cavity in the substance of the bone, the walls of which are of the compact bone imbedded in a surrounding mass of cancellous bony tissue. This distinction, however, should be made; that the internal ear has a much more complicated division of its inner space than the middle ear, and while the latter has one main cavity, fairly regular in shape, the inner ear has its cavity divided into compartments by the presence of laminae, both osseous and membranous in character.

The osseous wall of the inner ear, because of its irregularity in shape, surrounds a cavity which is known as the osseous labyrinth. Inside the osseous wall, not adherent to it except in a few localities, and following in general the irregularities of its wall, is a membrane which forms the membranous labyrinth. This membranous labyrinth is not exactly of the shape of the osseous labyrinth, but in the main it follows the contour of the walls of the latter. Between the osseous wall and the membranous wall is a serous fluid which is called the perilymph, while on the inside of the membranous sac is a like fluid that here is known as endolymph.

The inner ear is anatomically divided into three principal parts, the vestibule, semi-circular canals and the cochlea.

The vestibule. This is the middle chamber of the inner ear and in its walls are present several openings. In the posterior there are five openings for the semicircular canals, in the anterior is the opening into the canal of the cochlea, in the outer wall are two openings covered with membrane which are known as the fenestra ovalis, which the stapes is attached to, and the fenestra rotunda. In the inner wall are several openings for the passage of the various branches of the auditory nerve.

The membranous vestibule is within the osseous, and presents a constriction in its center which divides it into the saccule (anterior) and the utricle (posterior). It is with the former that the membranous cochlea is continuous while given off from the utricle are the three semi-circular canals. Branched from the narrow constricted neck which joins the saccule and the utricle is a blind dilation which is known as the ductus endolymphaticus. In the wall of both the saccule and the utricle is a small macula which is one of the terminations of the auditory nerve branches.

The semi-circular canals. These are three in number, so named because of their peculiar shape, and each one consisting of an osseous wall, within which is a smaller canal known as the membranous semi-circular canal. These three canals are each one placed on a plane at right angles to the other two, and at one vestibular termination of each one is a dilated extremity which is known as the ampulla. These canals are designated as the superior, posterior and lateral, and each has two terminations in the vestibule. The superior and the posterior canals, however, have at one extremity a common opening so that there are only three means of entrance for the four ends of these tubes.

Each one of these osseous canals is lined with a membranous canal which has a dilated extremity, corresponding to that of the osseous structure. In the three ampullae of the three membranous canals are three maculae which form the terminations of three branches of the auditory nerve.

The cochlea. This is the most complicated of the three divisions of the internal ear. It is placed anterior to the vestibule and is very irregular in shape.

To gain a clear idea of the shape and position of the cochlea in its relation to the vestibule of the inner ear, one should imagine an osseous column, hollow in the center, extending from the anterior wall of the vestibule toward the anterior, where it terminates in an apex. Wrapping itself around this shaft of bone, two and one-half turns, is an osseous canal, known as the spiral

canal of the cochlea, and this is directly continuous with both the osseous and membranous vestibule. The manner in which this continuation exists will be thoroughly described later.

Considering the spiral canal of the cochlea from the cross-section we determine that it is circular in shape, the walls formed by compact bone tissue. One wall of this canal, however, is always adjacent to the modiolus or shaft around which it is wrapped. Given off from this modiolus is an osseous lamina which follows the course of the canal from its base where it is continuous with the vestibule, to its apex which terminates in a blind extremity. This lamina extends as a spiral staircase, about one-half the way across the equator of the circle, thus partly dividing the spiral canal into two equal parts. This lamina of bone is known as the lamina spiralis ossea and the complete division of the canal is made by the basilar membrane which extends from the termination of the lamina spiralis ossea to the outer wall of the canal where it widens out to form the spiral ligament which attaches to the outer wall.

The spiral canal is now divided into two divisions, the one toward the vestibule being called the scala tympani, but the other half being further divided into two canals by another membrane known as the membrane of Reissner. This membrane extends from the termination of the lamina spiralis ossea to the outer wall of the canal further away from the vestibule, forming with the basilar membrane an angle of about forty-five degrees. The canal which is thus formed between the basilar membrane and the membrane of Reissner is known as the scala media, while that between the lamina spiralis ossea and the membrane of Reissner is called the scala vestibula.

To gain the idea now as to how these three divisions of the spiral canal are continuations of both the osseous and membranous vestibules, one must think of the scala media as the direct continuation of the membranous vestibule and the scala tympani and the scala vestibuli as continuations of the osseous vestibule.

Think of the scala media as a canal, the walls of which are formed by the basilar membrane, the membrane of Reissner, and an adherent membrane, which is attached to the outer wall of the spiral canal and extends between the other two. All three of these membranes are direct continuations of the wall of the membraneous vestibule, so that the fluid contained in the canal must be endolymph, which is continuous from the membraneous vestibule. The junction between the scala media and the membraneous vestibule is effected by a narrow constricted neck which is known as the canalis reuniens.

The scala media, however, does not extend entirely to the cupola of the spiral canal, but terminates before reaching this point, by the fusing of the membrane of Reissner and the basilar membrane. At the cupola then we have the canal divided into only two divisions, the scala tympani and the scala vestibula, which are divided by the basilar membrane and the membrane of Reissner. Through this fused membrane is a small opening, the helicotrema, which forms a means of communication between them, and allows the fluid of one to be continuous with that of the other.

The scala vestibula is directly continuous with the osseous vestibule, but the scala tympani has a membrane stretched across its lumen at the opening into the vestibule completely occluding it. In the base of the osseous wall of the scala tympani is an opening covered with membrane which is called the fenestra rotunda. This is an opening between the middle ear and the inner ear, and is the only opening in this wall with the exception of the fenestra ovalis which contains the base of the stapes.

The organ of Corti. This is the name given to that organ, resting upon the basement membrane and extending from the beginning to the termination of it, which contains the end cells of the largest single division of the auditory nerve.

The organ of Corti upon cross-section presents two rod-shaped cells, resting with their bases some little distance apart on the basement membrane, and with their apices joined to form a

pyramidal shaped structure. These cells are called the rods of Corti and the minute canal which is formed by them and the basement membrane is called the canal of Corti. Toward the lamina spiralis ossea from the inner rods are several rows of supporting cells resting upon the basement membrane, but not so long as the inner rods. These are called the inner supporting cells, and resting upon them is a single row of short hair cells which ascend to the height of the upper border of the inner rods where they terminate in a number of projections of protoplasm.

Outside the outer rods we have also several rows of supporting cells, similar to those supporting the inner hair cells, and these are called the supporting cells of Deiters. Resting upon them are three or four rows of outer hair cells similar in every respect to the inner hair cells. Outside the cells of Deiters are several rows of supporting cells of Hensen while still outside them are the supporting cells of Claudius.

Extending from the lamina spiralis ossea to the outer row of the cells of Deiters, but not coming in contact with the organ of Corti, is the membrane of Corti or the membrane tectoria.

The hair cells (about 12,000 outer and 3,500 inner) are the end cells of the sense of hearing and are the termination of the largest division of the auditory nerve. This division, known as the cochlear division, sends its largest branch through the opening in the central shaft of the modiolus known as the central canal of the modiolus, and from here are given off branches which find their way out through the lamina spiralis ossea by means of an opening through its upper and lower plates. These branches are continuous into the basilar membrane and from here ascend between the supporting cells and terminate in arborizations around the hair cells.

The auditory nerve enters the inner ear through the internal auditory canal, and divides into two main branches, the cochlear and the vestibular. The cochlear enters the central canal of the modiolus and is distributed as we have just described. The vestibular nerve is divided into two main branches, the superior and

the inferior. The superior branch gives off a branch to the macula of the utricle, a branch to the macula at the ampulla of the superior semi-circular canal, and one to the macula of the ampulla of the lateral semi-circular canal. The inferior branch has two divisions, one given off to the macula of the ampulla of the posterior semi-circular canal and one to the macula of the saccule. It is only the cochlear nerve which is considered as the true nerve of the sense of hearing, while the other branches have to do with other factors.

CHAPTER LIV

HEARING

Mental activities which are of different types are the result of impressions of different types carried along a nerve which may be apparently the same structure as another nerve which carries an entirely different impression. Certain nerve endings are capable of receiving only certain kinds of vibrations, and this is aptly shown in the study of the special senses.

In the study of the special sense of hearing we find that those longitudinal waves, in turn condensed and rarefied, have an effect upon the structures interposed between the hair cells of the cochlea and the outer world, and as a result sound is sensed.

Innate has so constructed the pinna of the ear, making it large and funnel shaped, that it serves to gather and concentrate the sound waves to its center, where is found the external opening of the external auditory meatus.

The external auditory meatus is merely a tube containing air, and it serves to transmit vibrations from the point of concentration in the pinna to the point of termination of the tube, which is the membrana tympani.

The membrana tympani, which serves to separate the cavity of the external ear from that of the middle ear, is composed of fibers stretched at different degrees of tension. When sound vibrations strike its external surface it vibrates in response to them.

The ossicles are three in number and have the function of vibrating in response to the vibrations of the membrana tympani. The malleolus has its long handle inserted into the membrana tympani and thus it vibrates; the incus articulates with the head

of the malleolus and so vibrates; the stapes is articulated with the arm of the incus so that it also vibrates as do the other two. Thus when the membrana tympani vibrates in response to external vibrations the ossicles also vibrate.

The eustachian tube, which extends from the pharynx to the middle ear, has the important function of maintaining the air pressure in the middle ear the same as that on the external. This is accomplished because the pharynx communicates with the external by means of the mouth and the nasal fossae and any tube or cavity communicating with it must maintain a like pressure. Occasionally because of a catarrhal condition of the fossae or the pharynx there is a swelling of the mucous membrane lining not only these organs but extending up into the eustachian tube. If this swelling progresses to a sufficient degree the tube may become entirely closed and there be no communication between the middle ear and the external air. Nothing is now present to tend to equalize the air pressure in the middle ear, and that on the external, and so the membrana tympani tends to bulge toward that side where the pressure is the least. This, of course, partly destroys the ability of the membrana tympani to vibrate and, as a consequence, hearing is somewhat impaired. This condition is known as catarrhal deafness or eustachian deafness.

Perilymph, the fluid which is contained in the inner ear between the external osseous wall and the membranous labyrinth, serves to receive the vibrations into the inner ear from the stapes of the middle ear through the fenestra ovale, and to transmit these vibrations through the scala vestibula, the helicotrema and the scala tympani to the termination of this latter tube in the fenestra rotunda.

The basilar membrane and the membrane of Reissner are thin membranes interposed between the perilymph and the endolymph through which the vibrations of the former pass and thus the vibrations are carried into the scala media. It is in the scala media that we have the hair cells located and as the endo-

lymph comes in direct contact with them they are caused to vibrate, and impressions of sound are thus transmitted from the peripheries of the cochlear division of the auditory nerve to the center in the brain, where the interpretation of these impressions gives rise to the perception of sound.

The fenestra rotunda has the function of offering itself as a means of escape for the vibrations into the cavity of the middle ear, where they are lost or pass out to the external, through the eustachian tube and the pharynx. The fenestra rotunda is placed at the basilar termination of the scala tympani, and the vibrations after passing through the scala vestibula, helicotrema and scala tympani emit here. The membrane stretched across its opening prevents the perilymph from finding its way into the middle ear, and the fact that it is present allows the vibrations to be much more fully expressed. To illustrate, we may imagine a metal tube filled with water, one end of which is occluded with a metal plug, and in the other end a plunger which vibrates. Water being very dense and not easily compressed, this plunger must of necessity have a short scope in which to vibrate. Now suppose the end of the metal tube, instead of a metal plug, had stretched across its opening a thin rubber membrane. Much greater scope is given to the vibrations of the plunger. So it is with the inner ear. The membrane over the opening of the fenestra rotunda serves as an elastic membrane, which allows for greater expression of vibrations in the inner ear.

ANALYSIS OF PITCH AND COMBINATIONS OF PITCH

The subject dealing with distinctions of pitch has long been a complex one, and even today physiologists are not agreed as to where and how this is accomplished.

We will first consider the pitch of a single tone and how the distinction is made. A tone of a certain pitch produces sound waves of a certain given length which cause the membrana tympani and all the intermediary structures between it

and the endolymph of the scala media to vibrate at a corresponding rate. Now the question arises as to whether there is located in the organ of Corti the necessary apparatus to allow for each given portion to respond to vibrations of a given pitch, or whether all parts of the organ of Corti vibrate in each sound wave and the distinction is made in the brain.

Located in the organ of Corti are about 15,000 hair cells which are the end cells of the sense of hearing. It is plausible that those at the upper or apician portion of the organ will vibrate in response to vibrations of a low pitch and those at the basilar portion will vibrate upon sound waves of a high pitch, the intermediate hair cells responding to intermediate pitches. If this assumption is taken we must follow the illustration further and maintain that as impressions carried along those nerve fibers which terminate in the apicial portion of the organ of Corti are interpreted in the brain the perception is one of a high tone, while if the impressions come from the fibers terminating in the basilar end, the interpretation would be one of low tone. In this event the interpretation of the impressions by Innate Intelligence would determine the perception of pitch.

The other theory advanced is that the hair cells all vibrate in response to all sound waves and that as a result of this vibration an interpretation is made in the brain by Innate Intelligence and the pitch is determined. This latter theory does not seem as plausible and is not borne out by experiments.

Combination of tones or mixed pitches present a more complicated explanation than does the simple pitch. We may have sound waves striking the membrana tympani of several different lengths. The question presents itself, Do different parts of the membrana tympani vibrate at different rates, and if so, how are all these wave lengths transmitted to the scale media? Here we must assume that no matter how many sound waves there are, they are all merged to form one wave, a combination of all. It need make no difference whether the first or the second theories offered above is taken, this fact stands preeminent.

The interpretation of this combination vibration by Innate Intelligence gives to us a knowledge of the different tones which are used in the formation of this combination vibration, instead of the interpretation being of one combination vibration alone. This is distinctly unlike the sense of vision, where the combination of vibrations from two different colors gives rise to the vibration from a combination color which appears as one.

The explanation of the interpretation which is put upon this combination vibration in the organ of hearing can only be made satisfactorily when we recognize the presence of the intelligence which we call Innate.

Nor is Innate Intelligence concerned alone with the interpretation of these simple or complex vibrations. She must maintain normality in all parts of the organ of hearing in order to receive the correct impressions. If a subluxation exists in the middle cervical region, giving rise to a catarrhal condition of the eustachian tube, there can be no communication of the middle ear with the external, and the result is an altered pressure which causes the membrana tympani to bulge one way or another. When this occurs the fibers cannot vibrate in response to the external vibrations because they are "out of tune," and as a result hearing is impaired.

The ceruminous glands must secrete just the right amount of ear wax to lubricate the external auditory canal, and this degree of secretion depends upon the ability of Innate to express herself by sending down the secretory impulses in normal degree. If a subluxation occurs and we have secretory impulses in excess, there will be a plate of wax formed in front of the membrana tympani and the external vibrations cannot reach the tympanum. The ear throughout is such a delicate instrument that its regulation offers an excellent example of the ability of Innate to control in even the smallest detail each and every part of the body, not controlling it as if it were independent of every other part, but concerning herself with making even the most delicate structures coordinate with the body as a whole.

CHAPTER LV

STRUCTURE OF THE EYE

The organ of vision is the eyeball, and it is contained in the orbital cavity or orbit, where it is embedded in a mass of supporting connective tissue containing much fat as a protective agent and also the blood vessels, nerves and lymphatics which extend to the eyeball and the surrounding parts. Here also we find the orbital muscles seven in number, six of which have a direct influence upon the position of the globe.

We will take up first the structure of the eyeball and the capsule around it, concluding with the surrounding structures and the orbital muscles which have to do with the movements of the eye.

CAPSULE OF TENON

This is the name of that thin sheath which extends around the posterior five-sixths of the eyeball, enclosing it, as it were, in a sac wherein it rotates. The inner surface of this capsule is smooth and between it and the outer coat of the eye is a small space, which is known as the perisclerotic lymph space and which is filled with a serous fluid which tends to lubricate the two surfaces that they may glide easily over one another. This perisclerotic lymph space is continuous with the subdural and subarachnoid spaces, and the fluid contained here is continuous with that found in these important spaces.

Piercing this covering at the posterior are the ciliary vessels and nerves and the optic nerve. The orbital muscles also pierce the capsule and they have extending along their courses for a short distance, projections, which finally blend with the fascia covering the muscles. At the sides of the eyeball we have the projections of the internal and external recti muscles given off

independently to form extensions to the lachrymal bone internally and the malar bone externally, thus acting as checks to an excessive movement of the eyeball to the sides. It is because of their function that they are called the check ligaments of the eye.

THE EYEBALL OR GLOBE

The eyeball is composed of two spheres of different sizes. The posterior of these two spheres forms about five-sixths of the entire organ, while the anterior and smaller sphere forms about one-sixth. These two spheres, uniting as they do to form one structure, present at the point of junction a slight depression, which is called the scleral sulcus. The line which is drawn from the center of the anterior sphere to the center of the posterior sphere and extended forms the optic axis, while the points where they pierce the surfaces are known as the poles. A line drawn on the surface of the posterior sphere equally distant from the two poles is called the equator. The globe is composed of three tunics or coats and three refracting media, which we will consider in order, beginning at the outside and concluding at the center.

The coats of the eye are three in number, outer composed of the sclerotic coat and the cornea, the middle composed of the choroid, the ciliary body and the iris, and the inner composed of the retina. In general it may be said that the outer coat is of a fibrous character, the middle of a vascular and the inner of nervous.

THE SCLEROTIC COAT

This coat is white in color on its external surface and brown on its inner surface. It forms the outer covering for the posterior five-sixths of the eyeball, and is pierced at the posterior by the optic nerve. This large nerve, however, does not enter through a single opening, but through a cribiform area formed by the crossing and intercrossing of the fibers of the sclerotic. It is through these many small openings that the different bundles of the optic nerve progress. On the inner surface are depressions and grooves for the accommodation of

the vessels and nerves of the choroid, although in general these two coats are separated by a small space known as the peri-choroidal lymph space. At the posterior, where the optic nerve enters, the sclerotic coat is continuous with the fibrous covering of the optic nerve, while at the anterior it is continuous with the cornea, which, together with the sclerotic, forms the outer coat.

THE CORNEA

This is the anterior continuation of the sclerotic coat, but differs from it in that while the latter is white on the external surface the former is transparent and colorless. Both of these two outer structures are characterized by their hardness, this feature being of value in holding the shape of the eye, and supporting the inner softer parts. The cornea is of uniform thickness and is found covering that part of the globe which is formed by the anterior projecting sphere. The shape of the cornea is almost circular viewed from the anterior, but upon transverse section reveals a concave inner surface and an outer convex surface. The degree of this curvature is variable in different individuals and in the same individual at different times of life.

THE CHOROID COAT

This is the structure of the middle coat which presents the greatest surface. It is found just interior to the sclerotic coat, with which it is connected by thin bands, known as the lamina fusca. It is of a dark brown color, and is essentially a vascular layer. In it are contained small arterioles, capillaries and venules, which form one of the most dense plexuses in the entire body. It is pierced posteriorly by the optic nerve and anteriorly it is continuous with the ciliary body which connects it with the iris.

THE CILIARY BODY

This small circular band is divided into three divisions, the orbiculus cillaries, the ciliary muscle and the ciliary processes.

The orbiculus ciliaris is a circular band, about one-sixth of an inch in width, which is merely a continuation of the choroid coat.

The ciliary muscle is found as a circular band anterior to

and within the orbiculus ciliaris. It is a muscular tissue composed of radial and circular fibers and comprises the main bulk of the ciliary body.

The ciliary processes are projections given off from the inner margin of the ciliary body, and are found over the entire circumference of that structure. About seventy in number, they act as points of connection with the suspensory ligament of the lens, and their anterior surfaces are in contact with the posterior surface at the margin of the iris.

THE IRIS.

This small body is the anterior termination of the middle coat of the eye. It is continuous with the anterior border of the circular ciliary body, and extends from here over the anterior, acting as a curtain. Near the center of the iris, a little toward the internal, is a small opening known as the pupil, through which light passes on its way to the retina. This opening is variable in size, altering as the degree of light alters. The iris is of many different colors in the human race, and this depends upon the quantity and quality of pigment which is deposited in it. In albinos, where the iris is pink in color, this is due to the fact that the pigment is deficient in quantity and the plexus of blood vessels can be seen through its layers. In the substance of the iris are muscle fibers, some of which are radial and some of which are circular. The former tend by their contraction to dilate the pupil, and thus increase the amount of light which gains entrance to the inner portion of the globe, while the latter by their contraction tend to decrease the size of the pupil and thus exclude light from the external. These muscles are known respectively as the dilator pupilae and the sphincter pupilae.

THE RETINA

This coat is formed by the nervous tissue, which does not extend over the entire sphere, but rather is found just inside the choroid coat, lining the posterior five-sixths of the globe. The retina is a spread out fan formation of the optic nerve from

The hyaloid membrane becomes thicker in the region of the ciliary body, and this thickened portion is termed the zonule of Zinn. This zonule is divided into two layers, the anterior one of which extends to the anterior surface of the lens, where it is attached near the equator of this little body and is termed the suspensory ligament of the lens. The other continues over the posterior surface of the lens as the zonule of Zinn, and forms the lining of the fossa patelaris. Between these two divisions of the zonule and the equator is a space which extends all the way around the lens, and it is known as the canal of Petit.

THE CRYSTALLINE LENS

The crystalline lens is enclosed in a transparent capsule of tissue, which is similar to elastic tissue, but differs from it in that the outer layers are of epithelial cells. It is thicker on the anterior surface than on the posterior, and when ruptured, curls up like elastic tissue in other locations. At the anterior the capsule is in contact with the posterior surface of the iris at the margin around the pupil; but at the outer border there is a space left between it and the iris which forms the posterior chamber of the aqueous humor. The posterior division of the capsule rests in the depression of the fossa patelaris.

The lens itself is about four mm. in its antero-posterior measurement and about ten mm. in its transverse and vertical measurements. It is a structure which is biconvex in shape, with the anterior and posterior surfaces meeting to form a line of union called the equator. At the center of the anterior surface and at the center of the posterior surface are the anterior and posterior poles, while the line drawn between these two points is called the axis of the lens. The anterior surface is less convex than the posterior. In structure the lens is composed of layers of transparent elastic tissue very much as the layers of an onion are placed until finally a small central core is formed. Although largely fluid in character, the lens contains more solid substances than either the aqueous or the vitreous humors, and when removed from the specimen holds its shape better.

The refracting media of the eye are three in number, and named from without inward they are the aqueous humor, the crystalline lens and the vitreous humor.

THE AQUEOUS HUMOR

The aqueous humor is a transparent jelly-like connective tissue which consists principally of fluid, containing about two per cent of solids. It fills the aqueous chamber, which is the space bounded anteriorly by the cornea, posteriorly by the crystalline lens and the suspensory ligament of the lens, and being divided into an anterior and a posterior chamber by the iris. Thus divided there is a means of communication through the pupil. The posterior chamber is a very narrow slit extending from the posterior surface of the iris to the anterior surface of the lens and the suspensory ligament. The anterior chamber contains the principal bulk of the aqueous humor and has its angle or circumference between the peripheries of the cornea and the ciliary body.

THE VITREOUS HUMOR

The vitreous humor is a substance very like the aqueous humor in structure. It consists of a fluid which is about two per cent solids and is transparent. It fills all that part of the eyeball posterior to the crystalline lens and enclosed by the inner layer of the retina. It is surrounded by a capsule which is also transparent, named the hyaloid membrane. Extending through the vitreous humor from the posterior surface of the lens to the poins of exit of the optic nerve is a canal lined by a continuation of the hyaloid membrane, and filled with a transparent fluid which, so far as structure is concerned, cannot be distinguished from the vitreous humor. This canal in foetal life accommodated the blood vessels which extended from the posterior part of the eyeball to the lens. In the anterior wall of the convex vitreous humor is a depression which is called the fossa patelaris. This is the only part of the surface of the vitreous humor which is concave, and it accommodates the posterior convex surface of the crystalline lens.

ings which are the beginnings of the lachrimal canals, and are called the puncta lachrimalae.

The eyelashes are rows of hairs arranged at the margins of the eyelids offering themselves as additional protection to foreign particles which might gain admission to the sensitive eyeball. The upper eyelashes are more numerous and longer than the lower, and they curve toward the superior, while the lower eyelashes curve toward the inferior. Situated in the eyelids are numerous glands, some of which are sweat glands and open at the margins of the lids, while the others are a variety of sebaceous glands called the Meibomian glands. These latter secrete an oily substance, which is emptied by small ducts on the margins of the lids near the roots of the eyelashes and is for the purpose of preventing adhesion of the upper and lower lids.

The conjunctiva is a membrane which is transparent and is found extending from the margin of the upper eyelid, where it is continuous with the integument, upward lining the inner surface of the lid. It ascends as this lining until it reaches a point where the capsule of Tenon terminates and here it is reflected upon itself and proceeds downward, forming the covering for the eyeball, and offering itself as a protective membrane to that structure. It proceeds on the eyeball to the scleral sulcus, where the capsule of Tenon ends and is again reflected upon itself as the lining of the lower eyelid, finally terminating at the margin of the lower eyelid, where it is continuous with the integument. The conjunctiva contains many minute mucous glands which serve to keep the surfaces lubricated that the eyelids may glide easily over the eyeball, and here we also find minute lymphatic glands. It is over the surface of the conjunctiva that the lachrimal glands pour their secretions, thus aiding the mucous glands in keeping the surface moist that there may be no friction between the eyelids and the eyeball. When the eyelids are closed there is a very minute space between them and the eyeball, so that the secretions of these mucous glands and of the lachrimal glands may be carried away through the lachrimal canals.

The lachrimal glands are two in number, one in each orbital cavity. Placed in the upper and outer angle of the orbit near the base, it lies in a depression of the frontal bone. It is about the size of a lima bean, with an upper convex surface lying in the concave depression and a lower concave surface resting upon the convex portion of the eyeball. It is placed just behind the scleral sulcus of the eyeball, although it sometimes extends forward far enough to project over the angle, where the conjunctiva is reflected upon itself. Extending from the lachrimal gland downward, forward and inward are from six to ten ducts, which carry the lachrimal fluid which it secretes to their points of emission between the two layers of the conjunctiva.

The lachrimal canals are two in number, having the origin in the puncta lachrimalae of the upper and lower eyelids, and extending inward and downward from here until they join, forming an ampulla which immediately terminates in the lachrimal sac. This lachrimal sac is placed in a depression at the junction of the lachrimal bone with the nasal process of the superior maxillary.

The lachrimal sac is oval in shape, supplied by these two lachrimal canals and drained by a third and larger duct, which is called the nasal duct.

The nasal duct extends from the point of origin in the lachrimal sac toward the inferior, where it terminates in the inferior meatus of the nasal fossa. It is about two-thirds of an inch in length and with the other parts of the lachrimal apparatus serves to carry the lachrimal fluid from the eye, downward into the nasal fossa.

ORBITAL MUSCLES

The orbital muscles are seven in number, six of which are attached to the eyeball. They are the superior, inferior, internal and external recti muscles; the superior and inferior oblique muscles and the levator palpebrae superioris.

The four recti muscles are so named from the fact that they pursue a straight course. They all originate in a fibrous

band or ring around the optic foramen at the posterior of the orbital cavity, extending from here toward the anterior, each lying in contact with the wall which its name indicates. Having reached the outer, inner, upper and lower borders of the eyeball they pierce the capsule of Tenon and are inserted into the sclerotic coat of the eye. Upon their contraction then they serve to turn the eye outward, inward, upward and downward.

The superior oblique has its origin just above the optic foramen, extending from here toward the base of the pyramidal shaped orbit. Arriving at the upper and inner angle of the orbit it passes through a tendonous ring, which acts as a pulley and is therefore known as the trochlea. The muscle then extends upward and outward, curving over the upper surface of the eyeball to its point of insertion between the superior and the external recti muscles.

The inferior oblique has its origin on the orbital process of the superior maxillary extending from here backward, and outward and finally upward to its insertion in the sclerotic coat between the external rectus and the superior rectus just behind the insertion of the superior oblique.

The levator palpebrae superioris is a long muscle which lies in the orbital cavity from its point of origin just above that of the superior rectus, to its termination in the upper eyelid. It extends through the orbital cavity above the superior rectus and at its anterior divides into three divisions, one of which passes to and is inserted into the upper tarsal plate, one to the integument of the eyelid, and one to the upper angle of the conjunctiva.

CHAPTER LVII

PHYSIOLOGY OF VISION

Our vision of objects is made possible because Innate Intelligence has so constructed the retina that the nerve endings here respond to vibrations of light. Light vibrations, while often compared with other vibrations, must be considered independently because while vibrations of sound are of material bodies, and are perhaps better transmitted by them, vibrations of light are entirely of ether, and are not magnified, but rather obstructed by solid objects. In brief the light vibrations are distinct from other types of vibrations and travel best through rarefied air or in vacuum.

Because light vibrations produce impressions upon the terminations of the optic nerve, and because the eye is so constructed that it alters these vibrations in their direction, it is first necessary that we concern ourselves with the physical laws and principals which have to do with the transmission of light vibrations.

For a long time it was considered that the transmission of light was instantaneous, but experiments have shown that it consumes time in its passage through the ether, the rate of which is about 186,000 miles per second.

If all vibrations of light are excluded from a room it is impossible for us to see most objects such as chairs, tables and other articles of furniture. There are, however, some bodies which are luminous, such as iron or other metals when heated until they glow. Most substances are luminous only when artificially heated to a high temperature, but a few materials, such as certain kinds of phosphorescent combinations are luminous even at ordinary temperatures.

There are three paths whereby light vibrations finally terminate; they are by reflection, absorption and transmission. Light rays proceeding from any luminous body strike an object and a certain percentage of them are reflected, that is turned back from the surface of that substance, to proceed in a different direction. Some of the rays are absorbed; that is, they progress for a short distance into the substance and thus terminate. It is only when the substance which the light strikes, is either translucent or transparent that the third path of termination is open. When transmission occurs, many of the light rays pass through the body and emit on the opposite surface.

As examples we may take a mirror, a piece of glass covered with lamp black and a transparent plate of glass. In the first instance none of the light vibrations permeate the silver on the back of the mirror, and because of the density of this substance few of the rays are absorbed by it; therefore, reflection occurs to a marked degree. In the case of the glass covered with lamp black, the light is not transmitted, neither does reflection take place to any marked degree, but absorption of the rays disposes of most of them. In the case of the transparent glass plate, very few of the rays are reflected, very few are absorbed, but the majority are passed through the plate to emit on the opposite side from which they entered. To illustrate the fact that even in transparent bodies much of the light is absorbed, we may take the example of clear water, which if only a thin film is considered, transmits sufficient light rays that objects are readily visible through it. However, it is a known fact that at great depths in lakes or in the ocean light is entirely excluded, due to the fact that the rays have been absorbed in their passage.

It is the fact that light rays are reflected which makes it possible for us to discern objects which in themselves are not luminous. In the case of these non-luminous objects, rays of light strike their surfaces and are reflected upon them to the human eye, where as vibrations they set up impressions which travel along the fibers of the optic nerve to the visual center in the brain where

interpretation takes place and Innate becomes aware of the size, shape, color and character of the object in question.

A ray of light, consisting of a series of etherial vibrations, always passes in a straight line, so long as the medium through which it is traveling is not changed. When this medium is changed, and the light ray leaves the air to pass through the other substance the rays pass in any one of the three channels which we have mentioned. We will first concern ourselves with the laws of reflection because it is upon this subject that the laws of refraction are based, and with this latter subject we are deeply interested because it is the process through which light rays pass in their course through the transparent structures of the eye.

REFLECTION

When an original ray of light (the incident ray) strikes a reflecting surface in any but the perpendicular direction it forms with the perpendicular line, striking the surface at this point (the normal ray), an angle which is equal to that formed by the normal ray and the reflection of the incident ray (the reflected ray). The incident ray, the normal ray and the reflected ray are all in the same plane. For example, if a ray strikes the reflecting surface, making with it an angle of thirty degrees, it must of necessity make an angle of sixty degrees with a perpendicular line extending from the point of intersection of the line with the surface. From here the reflected ray extends so as to also form an angle of thirty degrees with the surface and sixty degrees with the perpendicular line, and it lies in the plane, which is formed by the perpendicular line and the original ray.

REFRACTION

This is the term applied to the change which a ray of light undergoes in passing from one transparent medium to another of a different degree of density. A ray of light in the air travels at a rate of approximately 186,000 miles per second, but when it enters a transparent substance of greater density its velocity is de-

creased; furthermore, the direction which the ray has been following in the less dense medium is changed when it enters the one of greater density.

As in reflection, wherein the reflected ray lies in a plane formed by the perpendicular ray and the original ray, so in refraction the refracted ray lies also in the plane formed by the original ray and that which is normal to the surface. When a ray is passing from a body of less density to a body of greater density the refracted ray bends toward the perpendicular, while if it is passing from a dense medium to one of less density it bends away from the perpendicular.

In two substances of different density the angle which the refracted ray makes with the normal has a constant ratio with the angle which the original ray makes with the normal. As different substances of different densities refract the rays more or less when they enter the substance from the air, the angles of refraction which they make with the incident angle in the air is taken as a basis to compile an index of their refracting powers.

We then reach this conclusion: that the ray of light which passes from a less dense to a more dense medium, striking the surface separating them, in a perpendicular line, undergoes no refraction, and those rays originating from the same point which strike the surface at any other point are refracted toward the perpendicular. On the other hand if a ray of light passing from a dense to a less dense substance strikes the surface separating the two media in a perpendicular line, it does not undergo refraction, but all the rays emanating from the same point and which strike the surface at any other point than in the perpendicular are refracted away from the perpendicular. If a ray of light passes from a less dense substance through a denser substance and emits again into the primary material, and if the surfaces through which it entered and found its exit are parallel, the ray suffers no refraction, and the ray proceeds on the far side of the dense medium in a line parallel to the original ray.

We will now take up the proposition of a bi-convex lens,

illustrating how it refracts the rays of light, and in so doing focuses them all from a given point to a single point behind the lens. Passing through the two points which are the centers of the two convex surfaces is a line which is called the principal axis. Somewhere on this principal axis between the two convex surfaces is a point, the rays passing through which are not refracted. This is called the optical center of the lens. If the curvatures of the two convex surfaces are the same, this optical center is midway between the two surfaces of the lens.

Bearing this in mind it can readily be seen than an object in front of the lens which is sending out reflected rays from its entire surface projects these rays behind the lens in such a manner that those rays from the upper part of the object are focused at a point below the principal axis. It is for this reason that the object appears to be inverted and what appears to be right is in reality left.

We have now reached a point where we may make the application of these laws of refraction and the transmission of light through different transparent bodies. The human eye, and the eyes of many of the lower animals, are highly complex structures, but are so well regulated by Innate that the result of their actions are as clear and concise as those of the simplest organ. Because of this highly organized structure in the human body we must not imagine that the same exists in every animal. There seems to be no question but that many of the lower forms of animal life which are not endowed with the advantage which man has in this particular, are nevertheless enabled to distinguish different degrees of light, as is man even when the eyelids are closed over the eye. They seem to have end organs which are capable of receiving the impressions of light, but are not able to distinguish the outline of objects, to judge of their distance, color, etc. This would also be true in the human eye were it not for the refracting media here contained and the ability of these media to accommodate their shape to the distance from the eye of the object viewed.

When a ray of light progresses from some object to the

exposed surface of the eye it comes in contact with the layer of lachrimal fluid covering the conjunctive. It then passes through the conjunctive, cornea, aqueous humor, lens, vitreous humor and finally reaches the retina. In its passage through these various transparent substances, which are of different degrees of density, it must necessarily undergo refraction. When it enters the lachrimal fluid layer, conjunctiva and cornea, all of which have about the same refractive index (1.37) it is bent toward the normal. It then enters the aqueous humor (refractive index 1.33) which is less dense than the cornea and here, obeying the laws of refraction it is bent away from the normal. Starting on its journey through the lens, which is of greater density, then any of the other media of the eye (refractive index 1.43) it is again bent toward the normal, and finally entering the vitreous humor which has the same index of refraction as does the aqueous humor (1.33), it is bent again away from the normal. It can be seen then that the ray of light pursues four different directions in its passage through the refractive media of the eye, and to consider each one of these individually in the tracing of each light ray would be extremely confusing.

To avoid this confusion all these refracting indices are computed and an average is struck which may be illustrated by one single bi-convex lens, the two surfaces of which have certain constant radii of curvature.

Remembering that the angle of refraction always bears a constant relation to the angle of incidence in two media of known density, it can readily be seen that an alteration in the radii of curvature would produce changes in the degree of refraction, because it would change the angle of incidence and consequently the angle of refraction.

In the consideration of the eye reduced so that the refracted rays pass only through a single bi-convex lens rather than through four distinct refracting media, we must also consider the retina as a surface upon which these rays emanating from given points upon various objects, find lodgement and acting as vibrations, produce

impressions which are carried along the afferent optic nerve fibers and are interpreted in the visual center of the educated brain.

If a glass bi-convex lens is so adjusted as to concentrate the rays from a point behind it to a screen in front of it at a given point, it is not capable of focusing these rays at a single point upon the screen if the luminous point is brought nearer to it or taken further away. There are two ways in which accommodation may be made for this changed condition. Either the lens must be removed to a point nearer to or further from the luminous point or a lens with surfaces of different degrees of curvature must be introduced.

It is apparent that man is able to view objects at great distance or those at close range. Then this ability must rest upon the ability of the refracting media to change position or upon the ability of one or more of them to change their degree of curvature. The latter is the case. When focusing upon objects close to the eye, the crystalline lens is made more convex, while in focusing upon objects further away it is made less convex. This is due to the action of Innate Intelligence upon the ciliary muscle.

INNATE CONTROL OF VISION

We have gone into the laws of physics governing the passage of light rays through transparent bodies in order that a thorough understanding might be had of the mechanical changes which are necessary in the eye, and will now enter into the part which Innate plays in controlling the tissues of the eye in such a manner that they are able to take advantage of these unchanging laws.

Here we have a particularly striking example of the intelligence of Innate in understanding and utilizing these laws long before man educationally was aware of their existence. The primitive cave man looked out across the horizon, and then at some near object, not because of the fact that he understood these physical laws and educationally controlled the changes in the eye, but because he had an Innate which was as intelligent then as it is in man today, and which changed the shape of the lens in his eye

that he might see objects in close proximity as well as those at a distance.

Innate Intelligence becomes aware of a desire to look at an object at a certain distance and immediately sends out impulses to the ciliary muscle which produces just that degree of tension which is required upon the lens to focus it upon that particular object. When Innate contracts the ciliary muscle, it pulls forward on the choroid coat to which this muscle is attached and the tension of the suspensory ligament of the lens and the zonule of Zinn is made less so that the lens, which because of its elasticity is always tending to become more convex, bulges toward the anterior and posterior, and thus the curved anterior and posterior surfaces are made more convex and a focus is established upon a near object. If Innate sends out inhibitory impulses it produces a relaxation of the ciliary muscle and the lens is then held in a more flattened shape because of the traction put upon it by the choroid coat.

Nor is the effect of Innate Intelligence confined to the ciliary muscle. The radial and circular fibers which are found in the iris are also controlled by Innate. Here interpretations are made of impressions coming over the afferent fibers from the retina, and Innate becomes aware of the degree of light which is being admitted to the retina. If this is more than is needed to properly produce impressions here, motor impulses are sent to the circular fibers and they in contracting, decrease the size of the pupil so that some of the excess rays of light are shut out. On the other hand if upon interpretation Innate becomes aware that the light rays are not sufficient to properly act upon the retina, she sends out motor impulses to the radial fibers of the iris which constitute the dilator pupilae and the pupil is enlarged to admit more light rays.

The eyes are capable of being moved as bodies to different positions in the orbital cavity and this is accomplished through the orbital muscles, which upon contracting serve to turn the eyes to the right, left, upward or downward, and in doing so they are

capable of taking in different fields of vision without moving the head. This is accomplished through the orbital muscles, each one of which is controlled by Innate, and each one of which responds to impulses sent out by Innate over the nerves supplying those particular muscles.

It is not alone to the muscular tissue that Innate sends out impulses, but here as in every part of the body, there must be an adequate supply of nutritive impulses, reparatory impulses, etc., with which to keep not only the eye itself in proper condition, but also the tissues surrounding it, by which it is more or less affected.

SECTION XII

CHAPTER LVIII

BRAIN SYSTEM

The fact that the actions of many living organisms are controlled through the nervous system has long been known to mankind. This knowledge had been so long coupled with a superstition, however, that when investigators began scientifically to delve into the study of the nervous system, the pendulum inevitably swung in the opposite direction and every phase of its function was placed upon a material base which was as impotent to explain it as the original superstitious views.

Long ago the idea was prevalent that the nerves were minute vessels, in the lumen of which was contained a substance known as animal spirits. These traveled from one part of the body to another and in some mysterious manner controlled the functions of the various organisms. These animal spirits were thought to have their seat in the ventricles of the brain and to leave this home for the journey to other parts when the necessity required.

Upon the invention of the microscope a large field of investigation was opened in many phases and it was instrumental in leading to the further consideration of every portion of the human body, including the nervous system. In this latter field it disclosed the fact that the nerves were not hollow tubes but were made up of cells arranged in a definite order from the very center of the structure to the surrounding membrane. It disclosed the fact that each nerve was composed of funiculi and each funicilus of fibers. Further, it was found that the nerve branched and rebranched, giving off these fibers as units to the cells.

Science set herself at the task of explaining the function of the nervous system from the known scientific laws. Its instruments were taken in hand and each minute part of the brain, which was thought to be the center from which the control emanated, was reduced to its most minute form. Agents and reagents were utilized and the brain substance reduced to its essential elements. What was the result? Did science find something in the structure of the brain which explained the phenomenal control which it seemed to exercise over the rest of the body? No. The things which they found were the same elements which make up the dog, plant, the earth. Then science laid down her instruments, her chemicals and admitted that she could not even prove by the known laws that there existed such a thing as a mind, an intelligence. For the past several years there have been repeated attempts to establish the material proof which shall without fail determine the cause of every activity in the body as based upon scientific laws. This has often failed. Man is not an automaton, he is not a mere mass of chemicals arranged in a certain way and controlled by chemical and physical laws. Man is a thinking, reasoning, living being, and any conclusions drawn from a basis which does not advance outside the laws of known science, must of necessity be erroneous and misleading.

It must not be understood that the exhaustive research work on this subject in the scientific world has been productive of no good. The labors have been invaluable in determining just what part in the physiology of the body the laws of chemistry and physics are involved in, and it has done more than this. It has established without question the fact that man may not be classed as an automaton. That there must enter into his ego (speaking in the broad sense) something else, upon which these scientific principles must depend.

The nervous system is the medium by which the organs of the body are controlled, and the fact that this intricate mass of fibers all converge in the brain directly or indirectly, leads to the conclusion that here is the center, from whence are sent out im-

pulses to all parts of the body to operate and control it, and where are received impressions which upon interpretation become sensations. Science has undoubtedly proven by experiments, that something traverses the nerves, and for the want of a better term has applied the expression nerve impulse. This appellation will not stand the test of time, however. It was primarily adopted, perhaps, because impulse is a broad term which does not definitely stamp the force as anything in particular.

Another name has been applied to this immaterial, something which traverses the nervous system. It serves as a much more suitable term because it indicates more clearly, not the nature of the impulse, but rather the origin of it. If we will let our imagination wander, we may in a slight degree become aware of the magnitude of the universe and the absolute coördination of each part of it with every other part. Inevitably there arises in our mind the question as to what it is that controls the course of the planets, the growth of the tiniest plant. This force is called by various names by various peoples. It has been recognized and in a measure studied since time began. To it has been applied the name Universal Intelligence, not in any manner to belittle the other appellations of deity, but because it seems to express more fully the entire scope of its influence. By every individual in the world and by every living thing the influence of this Universal Intelligence is felt. In short we are all controlled by it, but at the same time each of us is different; each has an individuality of his own, and to that part of Universal Intelligence which controls each unit has been given the name Innate (inborn) Intelligence. Where this Innate Intelligence is resident is a question that is as far beyond us as the stars. This fact does, however, seem to stand pre-eminent; that the control which it exercises is through the nervous system. It is for this reason that the impulse which traverses the nerve fiber is given the name mental impulse rather than nerve impulse. In our opinion it establishes a closer connection between the immaterial Innate Intelligence which controls the cells of the body than any other term. What the nature

of this impulse is we cannot say. Derived as it is from an immaterial, it undoubtedly is an immaterial itself, even though it may be recognized by material change along the course and at the periphery of the nerve.

Anatomy is that study which considers the structure of living organisms. There are several subdivisions of this important subject, and among them is that of human anatomy, which is the most essential to us. Here the most careful analysis is made as to the composition of the various tissues and organs of the body, attention is given to the size, shape, color, etc., and everything which may be learned in regard to the structure is carefully considered. Human anatomy then deals with the concrete, the material, and when properly studied, does not advance outside this limit.

Philosophy is the collection of laws and principals pertaining to any particular branch of knowledge. It can be readily seen then that philosophy is an abstract subject, dealing entirely with laws and principals, and may be applied to any branch of learning. When considered in connection with man it deals with the principles by which man as a unit organism is controlled. This phase of philosophy is by far the most difficult to understand because man as the highest type of life is necessarily governed and controlled by the most complicated principals.

Physiology is the study of the function of living organisms, and human physiology is the study of the functions of the human body. Here we are face to face, not with philosophical problems alone, nor yet with the study of structure alone, but each must be blended with the other in such a way that the student may gain a conception of the manner in which the immaterial acts through the material and produces the mystic something which we call living matter.

From time immemorial there has been a great conflict between the material and immaterial. It is illustrated in the philosophy of religion and the establishment of science; between the

philosophy of life and the concreteness of medicine; between sociology and humanity.

In the dealing with the human individual this conflict is illustrated by the two extremes of medicine and mental healing. The former attempts to establish everything upon a materialistic basis, and when a certain chemical in the body is found by experiment to be absent, or as is more often the case, the physician assumes from the manifestations of incoördination that a certain chemical is absent, steps are immediately taken to compound a substance which shall as nearly as possible resemble that which is missing.

Mental healing on the other hand is concerned not at all with the physical body, but because thoughts are immaterial expressions, holds that when they indicate pain or incoördination, it is merely the manifestation of something which does not exist, and, therefore, is impossible. The one phase deals entirely with the material, while the other deals entirely with the immaterial.

It is not our intention to hold either of these ideas up to ridicule, but rather to establish the fact that in chiropractic physiology account is taken of both the concrete and the abstract, and to show that the two are so intimately blended with one another, that they cannot be separated in the living man.

Most physiologists have constructed their books on the basis that man is a mass of chemical elements peculiarly arranged, and controlled by nothing but the laws of matter. Some of them have stated in their preface that "the consideration of any special vital force is unnecessary, but that the term is used to explain somethings which they do not fully understand." How strange it appears to think of man, the living, thinking, reasoning being controlled by the same laws that operate in the inorganic world. If such an assumption be granted it would be impossible for man to die. The matter is there one minute after death as it was one minute before death; the laws which operate in the inorganic world are the same today as they were yesterday and as they have been from time immemorial; therefore, the individual could not die, and would always continue in the life which he had begun.

There must be something else with which the material is joined in order that the unit of life may be produced and continue. This something else is the immaterial, the abstract, the Innate Intelligence which is intimately associated with every living thing. Cognizance must be taken of both the abstract and the concrete in our study of the living unit, and this is the basis upon which chiropractic physiology is founded. We have studied the structure of the human body, and we have noted the action which is performed by these structures, but instead of looking for the cause of these activities in the laws of the inorganic world, we have associated them with the control of Innate Intelligence.

To state that this Innate Intelligence is located in any particular part of the human body would be as absurd as it is impossible. While we are not aware of this abstract except through its manifestation, still all deductions point to the fact that it operates through the brain and nervous system. Before any action, either Innate or educational, there is a mental process of reasoning, whether we are conscious of it or not. Thus, if we move our hand from one position to another, we first think the thought, and this mental process is followed by the expression of that thought in the action itself. Now, if all the nerves passing to that hand are severed, the thought of moving the hand cannot be followed by the action. This leads us logically to the conclusion that the factor which is productive of the movement is transmitted to the hand along the course of the nerve fibers. Considering that the nerve fibers over the entire body converge and centralize either directly or indirectly in the brain we are inevitably led to the conclusion that here is the center from whence all impulses of action originate. Again, if all nerves passing to the hand are severed the member undergoes degeneration and must of necessity die, and be no longer physiologically a part of the body. These basic principles have been known for a long time and it is a common expression to say that we think with our brain. This, however, cannot be granted, because if it were we would be forced to admit that chemical elements (this is what the brain is com-

posed of) possess the ability to think and reason. In other states of matter we know that there is no manifestation of this ability and so we must go beyond the physical brain and only admit that "we think through our brain."

Not only do we think through our brain, but the impulse resulting from this thought is transmitted through the spinal cord or cranial nerves, is conveyed through the spinal nerves, ganglia, etc., and is expressed through the tissue cells which function because of it. The abstract must pass through the concrete to produce physiological thought or action. When the passage of the abstract through the concrete ceases then nothing is left of us as individuals except the physical body, and we are dead.

The brain system is all that complicated system of nervous tissue which is found ramifying to and supplying every part of the human body. There are arbitrarily given two divisions which are known as the central system and the peripheral system. The central system is that portion which is found contained within the cranial cavity and the neural canal of the spinal column, while the peripheral system is that portion which is found outside these bony structures and extending from the central system to all the unit cells.

The central brain system is divided again into two main divisions known as the brain and the spinal cord, the former contained in the cranium and the latter extending from the foramen magnum at the base of the cranium through the neural canal. Covering this central system we have three layers of connective tissue, which serve to protect the very sensitive cord tissue from the surrounding bony walls. The inner one of these three membranes is known as the pia mater, the middle one as the arachnoid membrane, and the outer one as the dura mater.

There is no more complicated structure in the body than that of the brain and cord and for the purpose of description and study we will divide it into six divisions. The upper and main part of the brain is known as the cerebrum, and from this important structure we have extending toward the inferior a constricted

portion, which is known as the mid-brain. Below the mid-brain and connecting it with the upper dilated extremity of the spinal cord is the pons varolii or bridge, while joined with it and projecting toward the posterior is the small brain or cerebellum. The upper dilated extremity of the spinal cord which is found just below the pons varolii and continuous with it, is known as the medulla oblongata, and it in turn terminates below in the spinal cord which fills the neural canal.

The brain substance is formed by grey matter and white matter, the former consisting principally of cellular structure, while the latter consists of fibers given off from the cells of the grey matter. Extending through the substance of the brain and spinal cord is a canal which in the cord is known as the central canal, while in the brain it widens out to form four ventricles. The first two ventricles are known as the two lateral ventricles and are found in the lateral halves of the cerebrum. They connect with a small cavity in the median line and between them, which is called the third ventricle. Extending from the posterior wall of this latter is a canal which is known as the acqueduct of Sylvius, and it terminates in the fourth ventricle, a cavity which is found between the cerebellum, the pons, the medulla oblongata and the pia mater. It is with this fourth ventricle that the central canal is continuous. Piercing the pia mater, which forms part of the wall of the fourth ventricle is an opening which is called the Foramen of Magendie, and this serves as a means of communication between the subarachnoid space and the fluid contained in the central canal of the cord and the ventricles of the brain.

Brain cells are located in the grey matter but we cannot say that they are confined to this location alone. Every brain cell has several prolongations, some of which intermingle with the prolongations of other cells, but each has one principal prolongation known as the axis cylinder. This axis cylinder may extend to any part of the body, either through the medium of the spinal

cord or through one of the cranial nerves. This axis cylinder either medullated or non-medullated is the means whereby impulses are transmitted to or from the brain cell.

During the course of development, the epiblast is depressed along the course of the future spinal cord, forming the neural groove. This depression continues until the neural groove becomes the neutral canal, connected to the overlying epiblast only by a narrow strip of tissue known as the neural crest.

Soon this neural crest disappears and the neural tube surrounded by a mass of nervous tissue derived from the epiblast, is completely separated from the surface layer. From this long mass now begins to develop the entire nervous system. The neural tube becomes the central canal of the spinal cord and the four ventricles of the brain. The upper end of the nervous tissue enlarges to form the brain, while projecting from the posterior and anterior borders of the cord on either side are posterior and anterior roots which join with one another to form the spinal nerves, which emit from the intervertebral foramina. There is an anterior and a posterior root given off from either side of the cord, so two spinal nerves are formed at the same level, thus forming a pair. Projecting from the spinal cord are thirty-one pairs of these nerves, and they form the medium whereby impulses are transmitted from the cord to the tissue cells over the entire body, or impressions are carried from the tissue cells to the cord.

Along the course of the nerves, after they leave the brain, are often found minute or relatively large enlargements. These are called ganglia, and much dispute has arisen as to their function and the importance they bear to the brain system. Many authorities have claimed that the ganglia are small independent brains which have the power of responding to impressions the same as the cells of the brain have. This broad assumption, however, can hardly be granted. Primarily this conclusion was deemed inevitable because there were found in the ganglia cells which resemble the cells found in the brain. Naturally this led

to the belief that the functions were the same. Further experiments on specimens where the brain had been removed showed a marked activity upon the application of certain vibrations to the nervous tissues. This was all taken as an indication that the ganglion was an independent brain which had the same possibilities as are possessed by the brain.

Primarily the initial reasoning wherein it was assumed that because the structure of the cells in the ganglia was the same as that in the brain proof was established that the function was the same, cannot possibly admit of verification. We have many instances of where the structure of parts are apparently identical and yet they perform widely different functions. As an example we may consider the nerve fibers. Here it would appear that the fibers are identical and yet the application of vibrations to each of them produces entirely different results.

The argument that an activity is produced by the application of vibrations to the nervous tissue, even after the brain has been removed is of no weighty consequence when we realize that the experiment is being performed upon dead tissue and under conditions which are unlike those which exist during life. Further, the vibrations applied are usually of the electrical type, and we have no assurance that this stimulation is like the mental impulse which traverses the nervous tissue during life.

In support of the argument that all mental impulses which have to do with the controlling of function originate in the brain, and not in the ganglia along the nerves, we find that every ganglia is in direct communication with the brain substance through the medium of nerve fibers. Having already determined that the brain is the great center from which all mental impulses emanate, there can be no explanation for this feature except that the ganglion is an organ which, before it is capable of activity must receive its mental impulses from the brain.

It is a fact that the cells found within the ganglia, which send out their axones to the tissues of the body receive mental impulses from the nerve fibers which originate in the brain and end

in the arborizations in the ganglia. It is also true that the ganglion cells serve as distributing agents whereby the result of one impulse transmitted over one nerve fiber from the brain is productive of an expression in a large area because of the many cells in the ganglia with their many points of distribution.

In the consideration of the brain we learn that it is anatomically divided into two great divisions, one on either side, which have like centers, like structures and like cells.

Physiologically we also find that the brain is divided into two divisions, an Innate and an educated. The Innate brain may be defined as being that portion of the brain through which Innate Intelligence manifests itself by sending out impulses. The educated brain is that part over which we educationally have a greater or lesser degree of control, and one of whose activities we are educationally aware. The entire brain then is Innate and the educated brain is that division of the Innate over which we educationally have some influence. To illustrate, we have the act of digestion, which continues whether we are conscious of it or not, and educationally over which we have no control by the will. After we have eaten a meal we may go about other business, never give a thought to digestion, and yet that important action will proceed. The blood circulates, the serum separates itself from the blood, and many other functions occur over which we volitionally have no control. This is physiologically called Innate action.

Again we move our hand to pick up an object, before this occurs there is a conscious thought of what we wish to do, and so the action is accomplished. Without our first willing to do the thing it would never have been done. This is called educated intelligence, because our experience has taught us just what muscles to use in performing the act and to what degree they should be used. In brief, the action is controlled by the will. It would, however, be presumptuous to state that the power which caused the arm to move came from any intelligence within the scope of education. The power used in producing the act came

from Innate Intelligence, a part of Universal Intelligence which rules and guides the entire universe in its activities and destinies. It is only the guidance of this power which can be ascribed to that portion of mind which we call educated.

Not only is the brain functionally divided into an Innate and an educated portion, but the spinal cord, which acts as a cable through which the prolongations of the brain cells pass, is so divided. By this is meant that here are contained fibers some of which carry impulses which when expressed produce actions. This same division may be followed to the nerves which are given off from the spinal cord and to the cranial nerves which leave the brain and exit from the cranial cavity through individual small foramina.

While there is no difference in the histological structure of the nerves or the nerve fibers in different parts of the body their functions differ widely. Two nerve fibers may be of the non-medullated type, and to all appearances seem exact duplicates, and yet one fiber is known to convey mental impulses toward the brain and is an afferent nerve, while the other is known to transmit impulses from the brain and is called an efferent nerve.

We have said that functionally the brain, spinal cord and nerves emanating therefrom are divided into an Innate and an educated portion. It must not be understood, however, that there is no means of communication between the two divisions. It is definitely known that there are bands of intercommunicating fibers throughout the entire brain substance and that not only is one hemisphere joined to the other by them, but different centers which control different physiological actions are also connected.

This leads us to the consideration of the activities of the different parts of the body and the relationship which they bear to one another. The physiologist of the past has been too prone to explain every action as an independent one which has to do only with a certain vibration from one individual location. This, however, is too narrow an assumption. Every organ of diges-

tion normally functions in harmony with every other organ of that system. Each of these organs, before digestion begins, is richly supplied with its peculiar secretion, which it has stored in its cells. Upon the beginning of digestion each of these glands discharges its secretion into the alimentary canal, and each working in harmony with every other gland finally completes the process of digestion. The question now arises as to where this coördination of all these functions occurs. There is only one logical answer and that is through the Innate Intelligence. Here it is that an interpretation is made of all the impressions received from the afferent nerves and a number of perceptions are so formed. Each of these perceptions is considered and weighed with every other one and thus a conception is formed. As the result of this conception there is a unity of action of all the glands in the process of digestion which can only be explained by the common understanding of the Innate mind.

This unity of action reveals plainly the use of the intercommunicating fibers between the various brain lobes and centers. It is because of this physical connection that one specific process of reasoning is possible.

The Mental Impulse System

This name is given to that system in the body which has to do with mental impulses in any manner either in transmission or interpretation. It is used with the idea that it more fully expresses the entire process by which the body is governed than can be expressed in any other manner. Throughout the entire process of reasoning, in any physiological problem, the Innate control of the functioning cells of the body cannot be lost sight of, and as this is a control exercised by Innate Intelligence through the nervous system, both of these factors must be considered. In order to illustrate we will follow a voluntary action through the process of its execution and attend especially to the mental impulse system immediately before and after the action. First that portion of Innate which is guided in execution by the will, thinks

the thought of flexing the arm. In the brain cell there is a transformation which produces mental impulses and they are transmitted by means of the spinal cord to that level where the nerves are given off which control the flexor muscles. From here the mental impulses are conveyed by the spinal nerves to the tissue cells of the flexor muscles, and it is here that the mental impulse is expressed. The tissue cell in this particular instance expresses the impulse by becoming shorter and broader, thereby causing the entire muscle to become shorter and the arm to accommodate this changed position must become flexed. We have, however, at this stage only partly completed the cycle, which is the manifestation of the complete unity of action. The end cells of afferent nerve fibers which are located in the substance of the muscle receive vibrations which are the result of this changed position. The impressions thus received are conveyed back to the spinal cord by the spinal nerves and the spinal cord in turn conveys these impulses to the brain cell. It is here that the mental impulse undergoes interpretation, and as a result of this interpretation Innate Intelligence becomes aware of the fact that the position of the arm has been changed.

We are prone to speak of voluntary and involuntary functions. In our opinion it is better to speak of the actions as educated and Innate. Voluntary function is commonly taken to mean that function which is done in response to the will, while involuntary function is taken to mean that function which is done without the will acting.

Continuing under the basis already established we have learned that physiologically the brain system, through which Innate Intelligence is acting is divided into two divisions. One of these divisions we call educated intelligence and one we call Innate Intelligence. Bearing this in mind we may carry the comparison of two minds still further and safely maintain that each has a will. The educated intelligence has a will which is as intimately associated with it as that of the Innate Intelligence is as-

sociated with it. This being true all actions of the educated intelligence are voluntary to its control, while all involuntary actions are voluntary to Innate control. In the broad sense then, both educated and Innate actions are voluntary, and in order to make the terms used to express them more expressive of the true meaning implied the terms educated function and Innate function should be used.

Continuing under the same basis we should not define mental activities as conscious and subconscious because each is conscious to itself. Here also we class the mental activities and the two divisions of the mind as the educated and the Innate.

We have previously defined Universal Intelligence and have also stated that Innate Intelligence was that part of Universal Intelligence which was utilized in the production of function throughout life in any one living unit. For us to state where this Universal Intelligence is located, or in what manner the Innate Intelligence utilizes the brain cells would be impossible. We can only state that unlimited power is derived for use and that this power is transformed in the brain that it may be utilized in the physical body. Nor should we confine ourselves in conceiving of this Intelligence to its manifestation in man. It is equally important in the maintaining of health in lower animals, plants, etc., each of which have their own individual Innates.

We have certain parts of the body which are in part controlled educationally. Physiologically the educated brain receives its force from the Innate brain, passing this force through the power of voluntary education, before it is permitted to be expressed in the body. It is, however, erroneous to state that a certain tissue is entirely subject to the educated intelligence.

For instance, the skeletal muscles which respond to motor impulses sent from the educated brain are supplied with impulses sent directly from the Innate brain as well, and which are not subject in any way to the activity of the education. Nutritive impulses and impulses of expansion are examples of these.

Although the brain has been divided physiologically into the

educated and the Innate brain, another physiological division should be made wherein we have an afferent and efferent half, each of which balances the other in the quantity and quality of function. This is true because every function performed in the body is the result of an efferent impulse, and this efferent impulse is directly the result of the interpretation of an afferent impression conveyed to the brain from some part of the body. Therefore, the physiological activity of the afferent or the receiving portion must be the same as that of the efferent or the sending division.

The spinal cord is a cable of nerve fibers which serves to transmit impressions and impulses to and from the brain. In transmitting impulses from the brain the full quantity of transformed energy is given to it from the brain cells, for there is nothing to hinder this expression.

Here the same division must be made physiologically of the spinal cord as was made in the brain; namely, separating it into an afferent and an efferent division. The afferent division is that portion which conveys impressions from the point of entrance of these impressions into the cord to the afferent half of the brain. The efferent division is that portion which transmits impulses from the originating efferent cells in the brain to the point where the fibers leave the cord.

Having made the division thus far we must pursue it to the final termination at the peripheries of the nerve fibers and trunks, which are given off from the spinal cord as roots. Here we also have afferent and efferent fibers, which transmit impulses and impressions to and from the spinal cord, and physiologically the same number of impulses which are conveyed to the spinal nerves by the cord are conveyed to the tissue cells by the spinal nerves. Also the exact number of impressions conveyed from the tissue cell to the cord is transmitted through the cord to the afferent centers in the brain.

When the mental impulses are started from the brain by

Innate Intelligence to the tissue cell they traverse the path of the efferent nerve and the tissue cell is the hesitator at one end of the cycle, and this hesitation is consumed by the function which is performed, the quantity and quality of which is determined by the quantity and quality of energy conveyed to it by the mental impulse, which in turn is determined by the Innate Intelligence, which is controlling through the brain cells. The impression is then picked up afferently and carried to the brain, producing a continuous flow. At the brain, however, the impulse again hesitates during the process of interpretation, before it again starts on the cycle.

The quality of function is determined entirely by what quantity of action is performed here, and the quantity of the action in turn depends entirely upon what percentage of the normal mental impulses reach the tissues from the brain. If the percentage is one hundred then the action must be normal, and the function can express nothing but normality. This is for the reason that the quantity of energy transformed by the Innate brain is always sufficient for the function to be performed; not only for this particular function but the functions which are taking place in every part of the body at the same time, including the educated brain as well as itself. We then reach this conclusion: that the Innate Intelligence always transforms through the brain cells of the Innate brain a sufficient quantity of energy, and if this quantity is allowed uninterrupted passage from the brain cell to the tissue cell there must be normal function.

The function at the tissue cell is secured by two divergent routes, one of them is through the Innate brain, Innate spinal cord and Innate Spinal nerves to the Innate tissue cell. The other is from the Innate brain through the Innate spinal nerves to the educated brain. From the educated brain through the educated spinal cord, educated spinal nerves and to the educated tissue cell. These two routes may lead to the same tissue cell which we have designated as an Innate tissue cell, and as an educated tissue cell. In order to avoid confusion we must again

call attention to the fact that a tissue cell may be what is commonly called an educated tissue cell, because it responds to impulses carried along the educated nerve fibers, but it must always be considered also as an Innate tissue cell, because many of its impulses such as nutrition, reparatory, secretory, etc., are carried to it along the Innate nerve fibers.

We must here take cognizance of the fact that the educated brain cells before they are able to perform their functions of sending out impulses to the tissue cells, must first be supplied with transformed energy from the Innate brain cells. It then is essential in order that the educated brain as a whole shall be normal, that it be supplied by a normal quantity and quality of impulses from the Innate. It is only when this supply is cut off so that it does not reach the educated brain that we have any of the varied forms of insanity.

Every part of the body from the vertex of the skull to the soles of the feet, is supplied with mental impulses, some of which are first passed through the educated brain and some of which pass directly from the Innate brain to the tissue cell. These nerves, with the exception of a few recurrent branches in the cranium and the cranial nerves, emit from the spinal column in one of the zones from the atlas to the coccyx. The nerves emitting from these foramina of the spinal column supply a certain region which is similar in all individuals. For instance, the nerve fibers which emit from between the eleventh and twelfth dorsal vertebrae supply the structure of the kidneys with many different kinds of impulses. Motor impulses are supplied here, secretory impulses, sensory impressions pass along the afferent fibers of this trunk and other impulses which are essential in the metabolistic process. These impulses are all, with the exception of sensory, carried along Innate nerve fibers from the Innate brain without first passing through the educated brain. On the other hand, we find, emitting from between the first and second dorsal vertebrae nerve fibers which supply the muscles of the arm, over which we have an educational control. Here it is not necessary

that the secretory impulses should be supplied but the other functions are expressed here with the same degree of importance as in the kidneys. There is, however, the difference that the motor impulses before passing to the tissue cells, pass to the educated brain, and are from here sent out to the muscle, and the resulting action is an educated one.

Function then is of different character, based upon the kind of tissue supplied, the relevancy of this tissue to others surounding it, the quantity of the same, and the quantity of mental impulses sent to it.

We cannot correctly assume that all mental impulses are the same, although we must admit that experimentally there has been no distinction noted. The fact, however, that an impulse which is apparently identical with another, produces an entirely different function, leads us to the inevitable conclusion that the impulses must be different, because to assume that they were not would place directly with the tissue cell being acted upon, the ability to utilize the impulse as it sees fit. This cannot be true because all function and all variation of function is controlled by the Innate Intelligence through the brain and nerve fibers.

For the sake of convenience in distinguishing one type of impulse from another, Chiropractic has named nine primary functions, which serve to indicate the action which these impulses have upon the tissue cells. The nine primary functions are:

Motor—This is the function which has to do with the production of movement, and is expressed in muscular tissue.

Sensory—This function is that which is productive of sensations, either in the educated or in the Innate mind. It is the result of impulses carried by the afferent nerve fibers to the educated or Innate brain, whereby Innate or educated is made cognizant of conditions as they exist at the tissue cells.

Secretory—This function, as the name implies, is concerned in the production of fluids which are essential to some part of the body. Although all impulses which give rise to secretion are classed as secretory impulses, still they might be further separated

into as many divisions as there are different types of secretions in the body.

Excretory—This function is that which is productive of the formation of a substance in any part of the body which is no longer of use in the body, or which may be detrimental to it. It is well illustrated in the cells of the sudiferous glands, where those substances which can no longer be utilized are thrown out due to activity of the gland cells.

Reparatory—This function is concerned in the maintaining of normal tissue and to this end reparatory impulses are continually being sent to all parts of the body, because every tissue is continually being depleted.

Calorific—Here we have a function which is concerned in maintaining the normal temperature in the tissues of the body. This is essential because if one part of the body is too cold or too hot it is not in the proper condition to produce the best functional results.

Expansion—This function has to do with the expanding and filling out of the undeveloped tissue cells, and is, therefore, more active in foetal life and childhood than in adult life.

Reproduction—This, as one of the nine primary functions, is not utilized to the same degree as are the others, and is only expressed in the organs of generation. As the name implies it is that function which is concerned with the producing of a body of like kind.

Nutrition—This function is utilized in supplying to the tissue cells those impulses which are of value in building up the tissue cells and forming from the chemicals supplied the substances which become a part of the cell.

All nine of these primary functions are essential to the body in maintaining the metabolism, and it is to Innate that is left the task of sending each of the various kinds of impulses to those parts of the body where they are most needed. With the exception of the impulses of reproduction, all the primary func-

tions flow from the Innate brain to the educated brain, Innate realizing that they are all needed here. This is also true of the tissue cells, many of which are supplied by all the types of impulses except those of reproduction. Only one of these types of impulses flow from Innate brain to educated tissue cells, namely, motor. This we know because any impulse which does flow in this path must first pass to the educated brain cell, and from here to the tissue cell, and in doing so we would educationally become aware of its activity.

Life, harmony, health are synonymous terms used physiologically to express synonymous conditions. If the mental impulse supply from the brain cell to the tissue cell is normal the individual is in perfect health, the material and immaterial of which he is composed are in harmony and he is receiving and utilizing the true expression of life. If, on the other hand, something hinders this ability of the Innate Intelligence to express itself in the tissue cells, the health is not perfect, the material cannot be in harmony with the immaterial and the full expression of life cannot exist.

Health and disease are but questions of fluctuation in the degree of flow from the Innate brain to the tissues, the expression being health when the mental impulses are normal in quantity at the time they are expressed, and disease being the result when there is any degree or shade short of the normal.

As examples we have 100 per cent of brain transformation, 100 per cent of spinal cord transmission, and 100 per cent of spinal nerve conveyance, all of which must equal life, harmony, health and coördination between Innate Intelligence and Innate function; between the Innate brain cell and the Innate tissue cell. On the other hand, if we have 0% of Innate brain transformation, 0% spinal cord transmission and 0% spinal nerve conveyance, the result must of necessity be death, total and complete incoördination between Innate Intelligence and Innate function, brain and tissue cell.

Physiology, involving as it does the function of the body and each and every one of its many units, is properly concerned with the expression of that function to the fullest. When taken in this meaning it can and does not have anything in common with symtomatology or pathology. Viewed, however in the broad sense, physiology concerns itself with the explanation of movement in the tissue, and if this movement is not normal or is entirely lacking, the explanation of that deficiency would primarily be based upon physiology. It is impossible for anyone to tell what is wrong with a piece of machinery unless he is thoroughly acquainted with how that machine functions normally. He can then draw comparative conclusions and arrive at the decision of the incoördination.

It is with this explanation in view that we will now take up a condition which occurs along the course of the efferent cycle, and which is not normal.

We have transformed in the Innate brain 100% of impulses, which are transmitted by the spinal cord to the level where the nerve fibers carrying them emit from the spine. Here, then, is a traumatic condition characterized by a vertebra which is out of its proper position, thus decreasing the size of the intervertebral foramen and producing pressure upon the nerve fibers which emit from this opening. These fibers being pressed upon are not capable of transmitting all of the 100% of impulses which are transmitted by the spinal cord. Rather, because of the pressure of the nerve, it is able to convey only 50% of the impulses. As a result, then, of this condition, we have only one-half the proper activity, action, function or life between Innate Intelligence and Innate tissue cell.

It is readily understood how pressure on a nerve may produce the above condition, wherein the incoördination is characterized by a lack of mental impulses of a certain kind or character. When, however, we meet a condition wherein there is an excess of function we are at a loss to explain it by maintaining that it

is due to a nerve impingement. Here we cannot assume that a nerve impingement produces an excessive amount of impulses because then we would be giving to a mass of chemicals the power to produce the same function as is produced by Innate Intelligence. This cannot be. We must look for another explanation, and we find it in the fact that where there is an excess of any of the functions, it is directly due to the lack of another function, or the same function in another place.

This impingement on the nerve fibers may effect any of three sets of nerves, or perhaps a combination of two or all. First it may be upon the Innate nerves on their way to the educated brain, second upon the Innate nerves on their way to the balance of the body, and third upon the educated nerves on their way from the educated brain to the tissue cell. Further, it may effect nerves carrying any of the different kinds of mental impulses, such as secretory, excretory, motor, etc.

Recognizing this fact we can readily understand that the character of the incoördination in apparently the same part of the body may be varied. Thus if the nerve fibers passing to the liver cells, which conveyed the impulses of nutrition, calorific and reparatory were impinged the expression of this incoördination would be in some form of abnormality wherein there was the formation of pus. On the other hand, if the nerve fibers which convey the secretory impulses to these same tissue cells were impinged there would result the lack of secretion and the accompanying symptoms. Here are two cases which illustrate the two different types of incoördination which may exist in the same tissue, not due to any distinction in the tissue itself, but rather to the fact that in the one case different fibers are involved than in the other.

The spine consists of twenty-four movable segments, together with the sacrum and coccyx, and the spinal nerves, Innate or educated, afferent or efferent, which emit from the foramen between every two vertbræ which are in apposition, are subject

to impingement because of an abnormality in the position of the vertebra above or that below.

A subluxation is a condition wherein a vertebra or any other osseous structure of the body has lost its juxtaposition with the structure or structures with which it articulates, but wherein this abnormality is not of sufficient degree to be termed a luxation.

A subluxation interferes with quantity transmission either on the spinal cord or upon the spinal nerves at their points of emission, hence the quantity-quality of function is noted at the peripheries of all spinal nerves under pressure, this degree of function being relevent to the degree of pressure and the involvement of any one of the nine primary functions or perhaps to a combination of two or more of them.

An adjustment is the act of restoring the subluxated segment to its proper position, by the utilizing of force from the external, whereby this may be accomplished. An adjustment is sometimes accomplished by the utilizing of forces from the external which are not intended for the purpose of restoring the subluxated segment. This is, however, considering the term in the broad sense. To the Chiropractor, an adjustment is usually considered as a concussion upon the external surface of the body over the subluxated vertebra, of forces intelligently applied with the ultimate end in view of restoring the segment to its normal position, and which accomplishes this purpose.

When an adjustment is given the pressure upon the nerve fibers is released because the lumen through which these fibers are passing is increased in size. When this occurs it permits of a restoration of transmission whereby the mental impulses are allowed to pass freely between the Innate brain cell and the educated brain cell, or between the educated brain cell and the educated tissue cell. When this is accomplished quantity is again normal and quantity-quality function is again noted.

The Innate Intelligence of every individual is a fixed, stable,

eternal quantity in male or female, black or white, in any location in the universe, and in animals and plants as in man. Everywhere this quantity at the source is unlimited with ample in reserve to meet every ordinary or extraordinary need.

The nerve fibers, the material mediums between the brain cells and the tissue cells, are never destroyed except through the agency of disease or surgery, and even then clinical observation and physiological function points absolutely to the fact that an adaptative process occurs which rebuilds the depleted tissues to make the best of bad circumstances.

The only change that can occur on this material medium which carries mental impulses from the brain to the tissue cell and which carries impressions from the tissue cell to the brain is the pressure produced by a subluxation which interferes with quantity transmission.

We then arrive at this final conclusion: that material continuity between brain cell and tissue cell is permanent. That immaterial continuity between transformation and function is broken only in quantity by a decreasing of the carrying capacity, thus reducing functional activity. Material and immaterial continuity equals health. Material continuity and immaterial discontinuity equals disease, the subluxation being the intermediate which changes health to disease. The adjustment must then be the agent which by its restoring the subluxation to normal, restores disease to health.

INDEX